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AD B004564

AFFDL-TR-73-130
Volume II

THE STRESS ANALYSIS OF LOADED ROLLING AIRCRAFT TIRES

Volume II

Computer Program

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R. C. JOHNSTON
MATHEMATICAL SCIENCES NORTHWEST, INC.

OCTOBER 1973

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AIR FORCE/56780/25 February 1974 — 200

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Computer Program

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FOREWORD

The program described in this report reflects the research phase of the numerical facilitation of the hybrid stress finite element method for the large deflection stress analysis of multi-layered aircraft tires. The work was administered by the Air Force Flight Dynamics Laboratory, WPAFB, Ohio, under Contract Nos. F33615-72-C-1693 and F33615-73-C-3002 for the period of 10 January to 12 November 1973 under Project 1369, "Mechanical Sub-Systems for Advanced Military Flight Vehicles," Task No. 136903, "Landing Gear System Ground Contact Components for Advanced Military Flight Vehicles." Dr. H. K. Brewer served as the principal technical monitor for the Air Force.

The authors are indebted to Marianne M. Montgomery whose insight into the problems of large-scale computer program development has allowed the completion of the work leading up to this program.

The contractor report number is MSNW 73-303-1.

This technical report has been reviewed and is approved.

K. H. Digges

Kennerly H. Digges
Chief, Mechanical Branch
Vehicle Equipment Division
Air Force Flight Dynamics Laboratory

ABSTRACT

Presented is a description of the FORTRAN/COMPASS computer code for the large deflection stress analysis of multi-layered aircraft tires. The program is modulated into nine overlays within the framework of dynamic storage allocation and is operational on the CDC-6600 machine under the SCOPE 3.3 system.

TABLE OF CONTENTS

SECTION PAGE

LIST OF TABLES

LIST OF ILLUSTRATIONS

1. INTRODUCTION

The computer code for the stress analysis of aircraft tires is designed to solve the following problems:

- Inflation of the lifted but unloaded tire
- Rotation of an inflated but unloaded tire
- Contact problem of a statically loaded and inflated tire
- Contact problem of a loaded rolling aircraft tire.

The code is subdivided into eight overlays within the framework of dynamic storage allocation. In the first four overlays the input data is reduced to set up quantities associated with the geometrical configuration. The fourth overlay calculates the element stiffness and load matrices, which are assembled in the fifth overlay. The sixth overlay contains a direct equation solver with one right-hand side. For the contact problem, the seventh overlay generates the flexibility matrix coefficients using a direct multiple right-hand side equation solver. The actual contact problem algorithm is contained in the eighth overlay.

In the following section, the structure and modulation of the code will be described in detail.

1.1. Storage Allocation and Input/Output Characteristics

The data management of the computer code incorporates those primary features of the CDC 6600 system which are necessary for the efficient flow of large sets of information. Information storage and retrieval procedures were designed to minimize:

- Central memory required
- Input/output access time
- Program maintenance and modifications.

The following main features of the CDC 6600 system were used to achieve the above objectives:

- Random access input/output subroutines
- Unblocked, unbuffered files
- Blank common.

The random access subroutines are library input/output routines, supported by CDC, which provide the capability for direct storage and retrieval of records on a file, as opposed to sequential files which require accessing the records preceding the desired one. In the computer code, these mass storage routines are used extensively to store the

- Input data and
- Computed data

between overlays, which allows the program to

- Select,
- Input and
- Output

only those data which are necessary in the particular overlay under consideration.

Unblocked, unbuffered files are used to store the intermediate data; for instance, in the calculation of the element stiffness and element load matrix. These files are accessed repeatedly in a sequential manner. These unblocked, unbuffered files are efficient for reading and

writing large records, since the information is read directly from the disk into the program array area. Note that the records in blocked and buffered files would first be read into an intermediate system storage of the central memory area, and then transferred into the program array area.

The proper use of blank common allows the code to have a general work area available, whose length depends only on the field length declared on the job card. This area is dynamically divided among the arrays needed in executing the current overlay.

Thus, the central memory disposition of the codes have the following structure:

word 1

system area
labelled common
program instruction, variables, arrays, and file work area
blank common

last word (= declared field length)

The above construction allows the user to specify a field length tailored to the data size.

In the current code, each overlay determines the length of the arrays used and stacks them nose-to-tail in blank common.

The current code uses no tapes. It is realized that this feature is essential in modern technology and thus we propose to perform all improvements in the "no tape" philosophy.

1.2. Fortran Extended Code

Two versions of the code are provided, one produced via the RUN compiler and the other the fortran extended (FTN) version. The RUN version varies from the FTN version by its IF UNIT tests, presence of RETURN statements in overlay main programs and its compass decks.

All of these are provided.

1.3. Library Routines

Besides the standard library routines, the codes employ the following special features of the CDC 6600 library:

- BUFFER IN
- BUFFER OUT
- READMS
- WRITMS

1.4. Assembly Language Subroutines

The CDC 6600 assembly language, COMPASS (COMPrehensive ASSembly language), is particularly suited to substanially reducing the computation time of looped operations. The improvements are realized by:

- More efficient retrieval of array elements
- Overlapping of data storage and retrieval from central memory with multiplication, addition and subtraction
- Efficient use of the instruction stack which holds seven words (up to 28 instructions) in the central processor.

Well coded compass routines will execute computational do loops from 5 to 6 times faster than normal Fortran IV on the CDC 6600.

In the present code, six of the heavily used matrix manipulation subroutines are written in COMPASS:

- MATMPY
- MATADD
- MATSMP
- INPRDS
- VECMAT
- EMULT

There are six special compass subroutines to perform tasks which standard Fortran IV is not designed to handle. These are listed below:

- KFL
- SSZERϕ
- MSTG
- GET
- PUT
- STRMϕV

KFL is a COMPASS subroutine which retrieves the field length requested by the job. This information allows the program to use all central memory available. Furthermore, for each data set, a minimum field length requirement may be tailored.

SSZERϕ is designed to set array values to zero during execution in a minimum amount of time. The routine is used extensively throughout the code.

MSTG, GET, PUT, and STRMϕV are COMPASS routines which perform character and string manipulation. They are used in dynamic storage

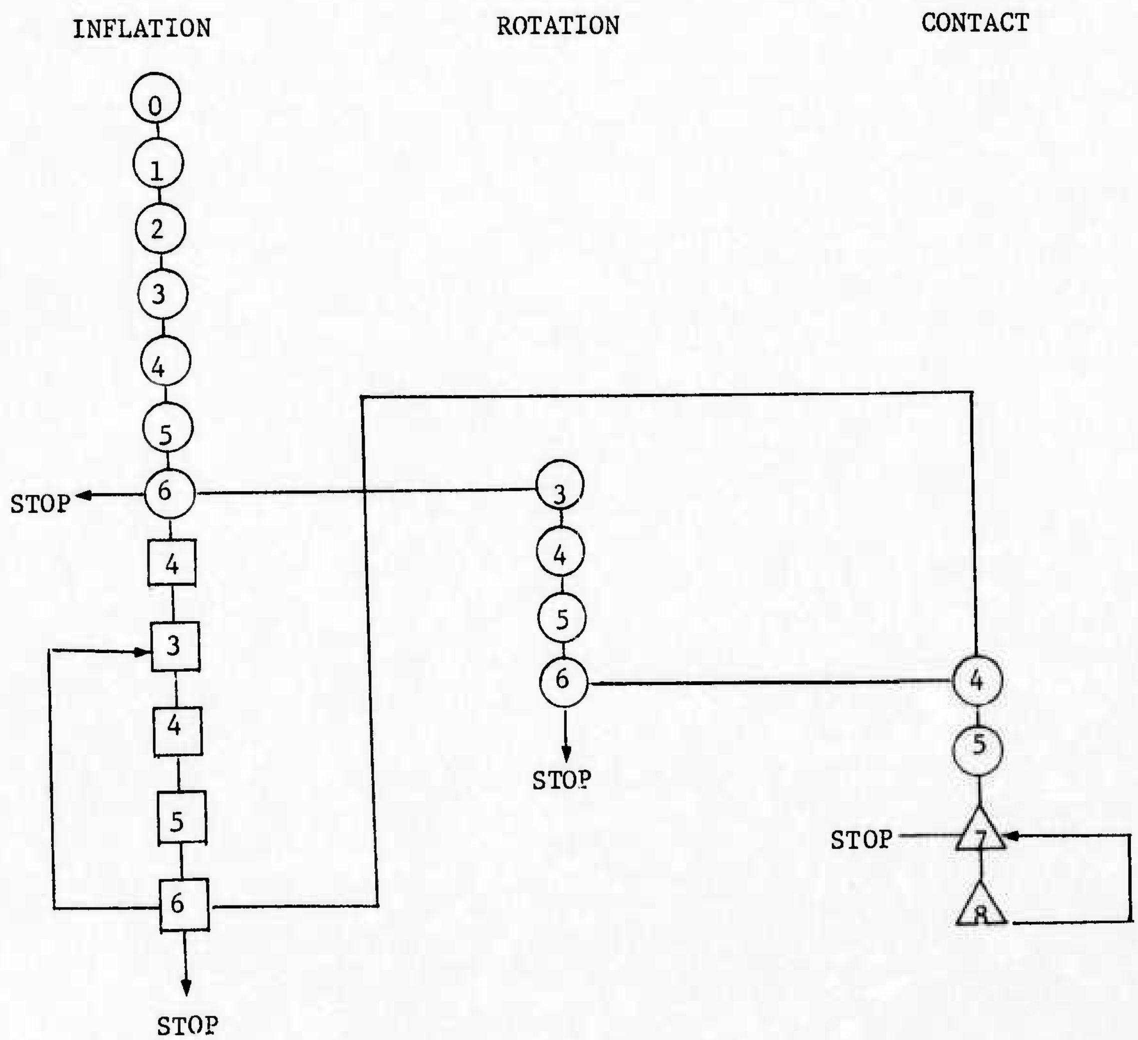
allocation and by the free field input reader which reduces considerably the time requred by the user to enter and debug his input data.

2. PROGRAM ORGANIZATION

The program is organized according to the following problem types:

- inflation
- inflation and rotation
- inflation and contact
- inflation, rotation and contact

The general data flow is shown below, where the numbers refer to the overlays under consideration.



In the above data flow the symbol $\square$ refers to the incremental inflation process. The symbol $\triangle$ refers to the contact iteration algorithm.

3. OVERLAY DESCRIPTION

3.1. Overlay (KTIRE, 0,0)

This overlay controls the general data flow as described in Section 2. It performs the initialization of labeled common blocks, opens random access mass storage files and facilitates the storage requirements within the framework of dynamic storage allocation. This overlay also contains various utility programs and assembly language routines for vector and character manipulations.

3.2. Overlay (KTIRE, 1,0)

All the input data are read from cards in this overlay and then they are placed on random access mass storage files. The input data are checked for logical errors which are summarized at the end of the data processing phase, using the subprograms RANGE, WRDCHK and COMPCHK. The primary control parameters are also set up here in the labelled common blocks SIZE and CONTACT.

3.3. Overlay (KTIRE, 2,0)

This overlay performs the preliminary nodal calculations such as

- cartesian and curvlinear coordinates
- surface vectors of the undeformed reference surface
- cord angle distribution along the meridian.

The resulting data are placed on random access mass storage files.

3.4. Overlay (KTIRE, 3,0)

The intrinsic reference element properties, such as

- element area
- element centroid
- local unit vectors
- local element vertex coordinates
- average cord angles

are generated here and then placed on random access mass storage files.

3.5. Overlay (KTIRE, 4,0)

This overlay sets up the element stiffness matrix and load vector according to the hybrid stress finite element formulation outlined in [1].

In principle, the element complementary energy matrix and the boundary work by the stress resultants are calculated here, followed by the elimination of the undetermined stress coordinates using an out-of-core Choleski decomposition algorithm.

In particular, it performs the calculation of the

- element flexibility matrix
- element flexibility vector
- homogeneous incremental flexibility matrix
- incremental element flexibility vector
- particular incremental element flexibility matrix
- hybrid element load matrix
- hybrid element load vector
- incremental hybrid element load matrix.

Since all these element-wise calculations involve out-of-core processing, the theme of fourth overlay is established by the Choleski inversion routine and best explained by considering the main calling sequences as follows.

In Table 1 the key subroutines have the functions

- CUBRE sets up the Gaussian weights/nodes
- TRCALC sets up the transformation matrix in the local coordinate system for the lamina constitutive relations
- DCALC, SCALC calculate the lamina compliance in a principal frame from the constitutients elastic properties.
- ENER performs the calculation of the complementary energy matrices as indicated by Table 1.
- HBMERGE merges the layer complementary energy matrices due to homogeneous stress field to obtain the element flexibility matrix $C_{\beta\beta}$, as described in Section 3.1.10 [1].
- HAMERGE merges the layer complementary energy matrix due to homogeneous and particular stress field to obtain the corresponding element complementary energy matrix $C_{\beta\alpha}$.
- PQMERGE merges the incremental layer complementary energy matrices to form the corresponding element complementary energy matrices $\Delta C_{\beta q}$ and $\Delta C_{\alpha q}$.
- WORK calculates the work done by the stress resultants on the reference surface displacements.
- PRESF sets up the external load vectors

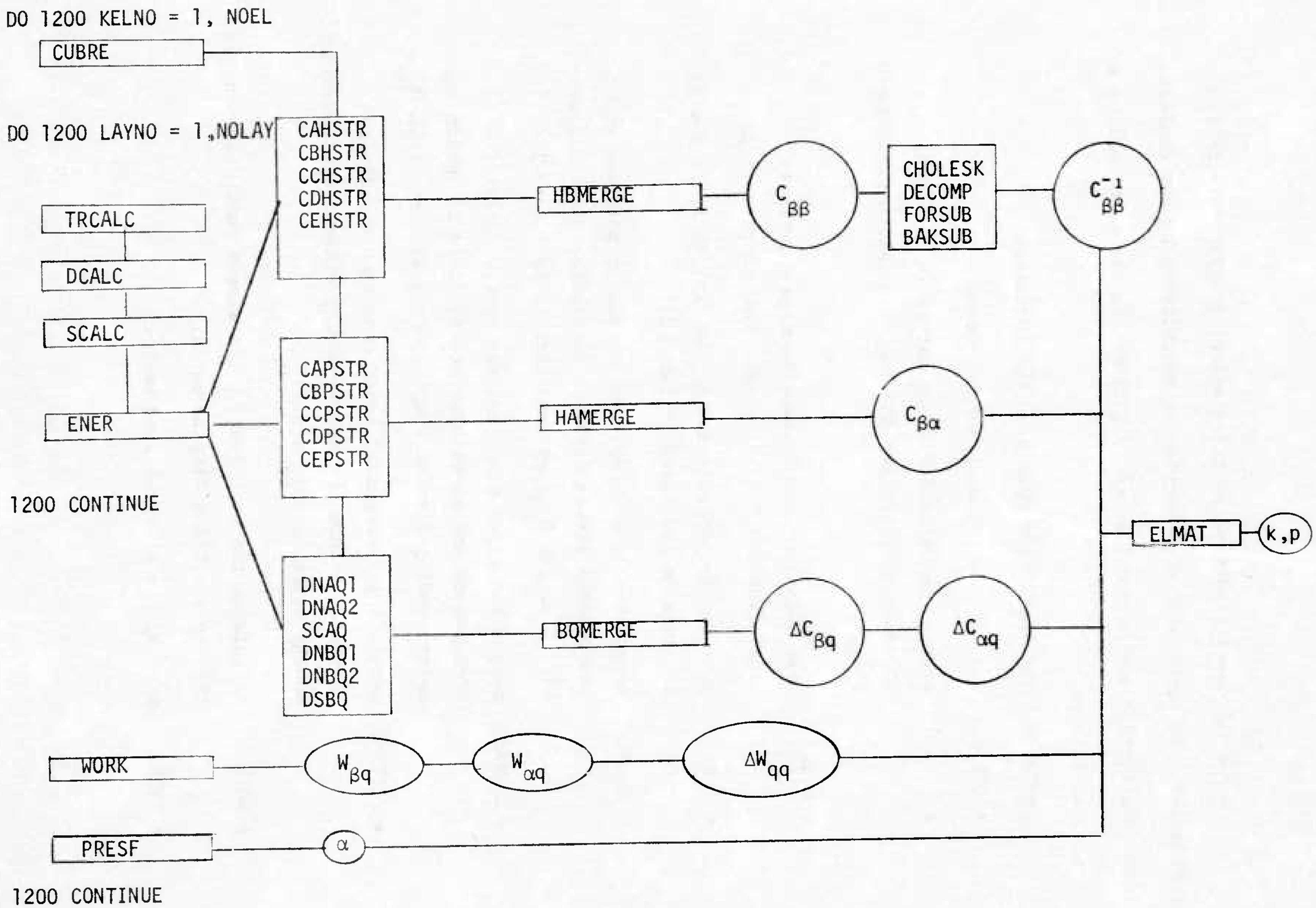


Table 1.
Data Flow of the Fourth Overlay

- CHOLESK DECOMP FORSUB BAKSUB — performs the inversion of the element flexibility matrix $C_{\beta\beta}$ using a Choleski decomposition procedure which takes into account the banded symmetric and staircase structure of this matrix.

- ELMAT — forms the element stiffness matrix and load vector according to Equations (3.1.16) of [1].

- CAHSTR : DSBQ — perform the area integrations using numerical cubatures as described in Section 3, Vol. I.

Note that a single pass at the fourth overlay sets up the element stiffness and load matrices. After assembling these in the augmented structure stiffness matrix and solving for the general displacements, one must sweep overlay four the second time to fetch the stress coordinates, using Equation (3.1.1.3) of [1] to obtain the layerwise stress distribution for each element.

3.6. Overlay (KTIRE, 5,0)

This overlay constructs the structure stiffness matrix for all the problems under consideration, and the structure load vectors for inflation and rotation problems.

The corresponding merge routine takes into account the banded and symmetric properties of the structure stiffness matrix which is augmented by a single load vector. According to the problem-size under consideration, this augmented matrix is subdivided into row-wise blocks for out-of-core processing. Each block is then placed on a random access file, so that the element stiffness matrix and load vector components may effectively be placed in the appropriate block under consideration.

After assembling, the homogeneous displacement boundary conditions are applied by zeroing out the corresponding rows and columns of the augmented structure stiffness matrix and placing a finite number in the diagonal.

For the contact problem, the same merge procedure is used, however, the structure stiffness matrix is augmented by multiple right-hand sides to obtain the appropriate flexibility matrix components required for the facilitation of the contact analysis.

3.7. Overlay (KTIRE, 6,0)

A standard Gaussian elimination routine is contained here which takes into account the banded and symmetric properties of the structure stiffness matrix, which is set up according to Section 3.6. The appropriate inner-product operations are coded in COMPASS as exhibited by the EMULT subroutine.

This overlay is assessed at each incremental step during inflation and also for the rotation problem. After each pass, the resulting solution vector is used to update the geometrical configuration according to the intrinsic initial stress formulation.

3.8. Overlay (KTIRE, 7,0)

This overlay sets up the appropriate flexibility matrix coefficients for the contact problem, which are obtained by a direct multiple right-hand side equation solver, called SOLVMOR. The relevant inner product operations in this routine are coded in assembly language with double overlapping, EMULT.

For the contact problem the global coordinate system is a cartesian reference frame. The appropriate element stiffness and load matrices are calculated in the fourth overlay. The structure stiffness matrix, as for the inflation or rotation problem, is again constructed in the fifth overlay.

The seventh overlay reads the above structure stiffness matrix and augments it with appropriate unit vectors defined by the candidate contact nodes under consideration. The corresponding flexibility matrix coefficients are then obtained from SOLVMOR, which destroys the structure stiffness matrix during the reduction process. Thus, during the contact iteration, the structure stiffness matrix is re-fetched from the mass storage files created by the fifth overlay.

3.9. Overlay (KTIRE, 9,0)

This overlay performs the iterative contact analysis as described in Section 3.2 [1].

4. FILES AND COMMON BLOCKS

The program control variables are transmitted via labelled common blocks, while the relevant input or calculated data are placed on sequential or random access mass storage files.

4.1. Common Blocks

BCINDEX contains the information for dynamic storage allocation:

- NOPOS or number of positions available for allocation.
- KSPACE or space available for allocation.
- INDEX or pointers to currently defined arrays

CONTACT consists of the information for the iterative contact algorithm:

- NORING or number of contact rings
- KRING or current ring number
- NODMAX or maximum number of nodes in a ring
- KSZAX or total number of candidate contact nodes

ERROR accounts for all logical input data errors and includes the following informations:

- NERR or running count of input errors
- NERRS or record numbers of those with errors
- NERLIM or maximum number of errors to be counted
- KERR or indicator as to whether current block has errors.

FILES contains the names of all data files defined by Fortran IV Hollerith form.

INDTA is comprised of information about the last record read by the input reader:

- NWRD or number of items present
- ITYP or type of each item present
- NREC or record number
- NCRD or card number
- DTA or value of each item in the record

MATSIZ consists of the structure stiffness matrix characteristics:

- NUMBK or number of blocks
- NBKSI or block size
- NMIQ or bandwidth including right-hand side.
- NPB or nodal points per blocks
- NEQ or number of equations per blocks
- NMAX or total number of equations
- NORHS or number of right-hand sides
- NRBKSI or the size of the flexibility matrix block

PRINTS controls all optional intermediate printing:

- KPRINT or an array indicating which intermediate values the user wants printed
- LINLIM or the maximum number of single spaced lines per page.

RECORD contains the variable names for all named random access records.

RETRIV consists of information to determine the blocksize of the structure stiffness matrix:

- LENCOM or the address of the beginning of blank common for each overlay.

SIZE is comprised of the input control parameters:

- NOEL or number of elements
- NNODE or number of nodes
- RADIUS or radius of meridian reference curve rotation
- NRHO or number of fitting coefficients for the meridian reference curve
- NPRHO or number of data points for the meridian reference curve
- MAXLAY or maximum number of layers
- GREEN or green angle
- SPEED or rotational speed
- INCR or number of increments for nonlinear inflation.

4.2. Sequential Files

All the values contained in the files described below are directly calculated in the fourth overlay. File descriptions are given in Table 2.

Table 2

Sequential File Description

File Name	Contents	Size	How Many Generated
KBMAT	B matrix used in ELMMAT	Maximum 315 words	One record per layer
KBQMAT	BCBQ matrix used in ELMMAT	Maximum 315 words	One record per layer
KHAMAT	HP matrix used in ELMMAT	Maximum 189 words	One record per layer
KHBMAT	H matrix to be inverted via CHOLESK inversion	Maximum 378 words	One record per layer

4.3. Random Access Files

Following is a description of all records of all random access files. The fourth table entry indicates whether the information is input or calculated by the code.

Table 3

Random Access Files

File Name	Record Name	Contents	I/C	Size
KCTMAT	KCTC	Contact data	I	NORING * (NODMAX + 2)
KCTMAT	KCTC2	X Coordinate Array-Contact case	C	KSZAX
KCTMAT	KCTC3	Contact Case ALPHA array	C	Maximum KSZAX
KCTMAT	KCTC5	Total Nodal Load Vector-Contact Case	C	Maximum KSZAX
KHMAT	Numbered one/layer	Decomposition of the HB matrix	C	Maximum 378
KLADAT	Numbered one/element	Element Layer Data	I	Maximum MAXLAY *10
KONDAT	KAR	Elements areas	C	NOEL*1
KONDAT	KAV	Average Cord Angles	C	NOEL*1
KONDAT	KBETA	Curvefit betas	I	NPBETA*2
KONDAT	KCA	Cord Angles	C	NNODE*1
KONDAT	KCAR	Cartesian coordinates	C	NNODE*3
KONDAT	KCARC	Cartesian Data	I	NNODE*6
KONDAT	KCEN	Centroid	C	NOEL*3
KONDAT	KCLC	Curvilinear coordinates	I	NNODE*2
KONDAT	KDIS	Displacements	I	NNODE*6
KONDAT	KELN	Elements' Nodes	I	NOEL*3
KONDAT	KFOR	Forces	I	NNODE*3
KONDAT	KINCR	Nonlinear Increment Data	I	INCR*2
KONDAT	KIPV	Inplane Vertex Coordinates	C	NOEL*6
KONDAT	KLUV	Local Unit Vectors	C	NOEL*9
KONDAT	KRHO	Curvefit Rhos	I	NPRHO*2

File Name	Record Name	Contents	I/C	Size
KONDAT	KSV	Surface Vectors	C	NNODE*9
KPMAT	Numbered one/element	Upper half element load & stiffness matrix	C	135 words
KRMAT	Numbered one/layer	The H^{-1} matrix after forward substitution	C	Maximum (NOLAY*21-7) *21
KSLMAT	KSLV	Solution vector	C	NNODE*5
KSTFIL	Numbered-one per merged block	Output merged K matrices	C	Maximum NEQ* (KBAND+KSZAX)
2	Numbered one/block	SOLVMOR solution	C	Maximum NEQ* KSZAX

4.4. Data Flow Chart

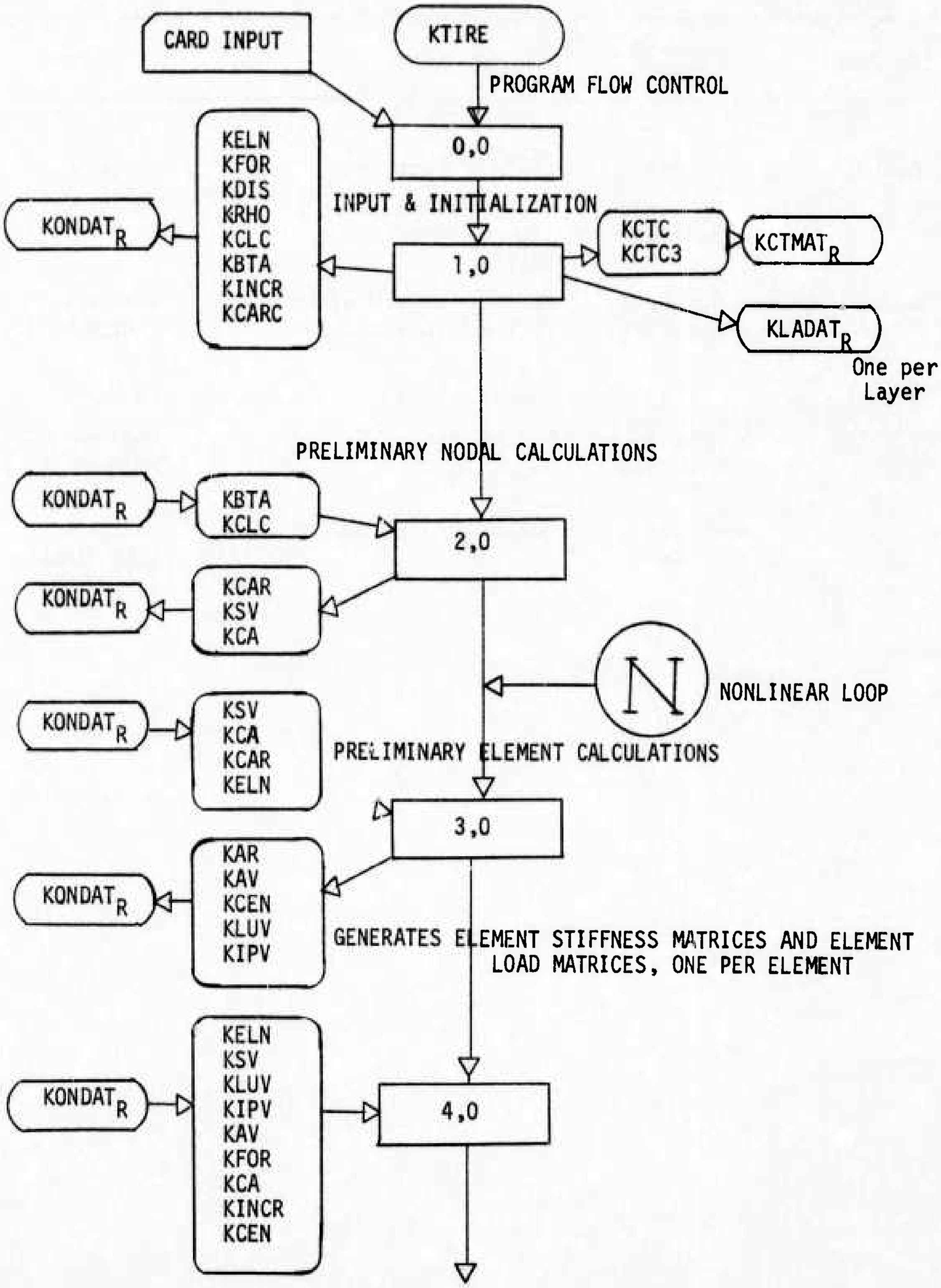
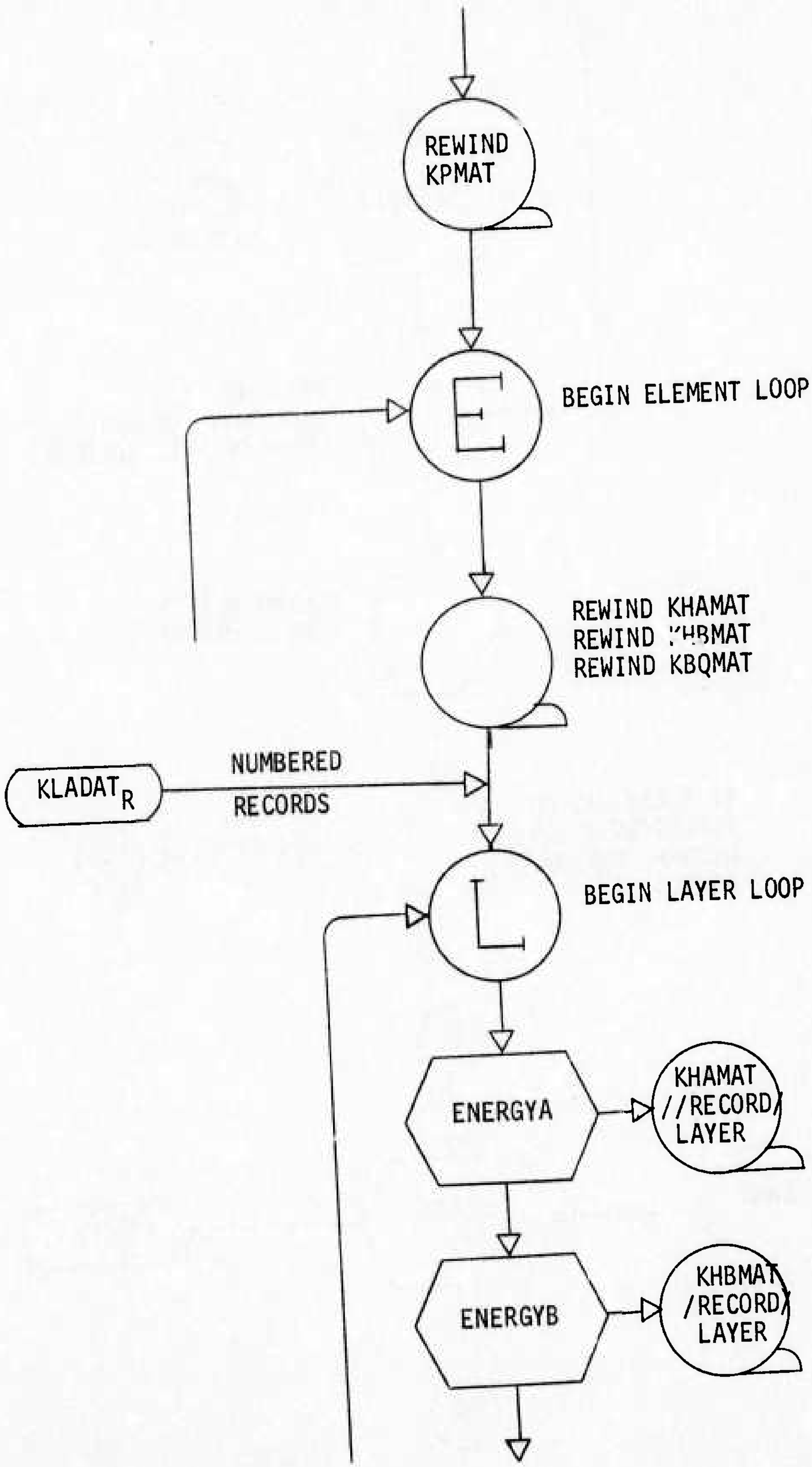
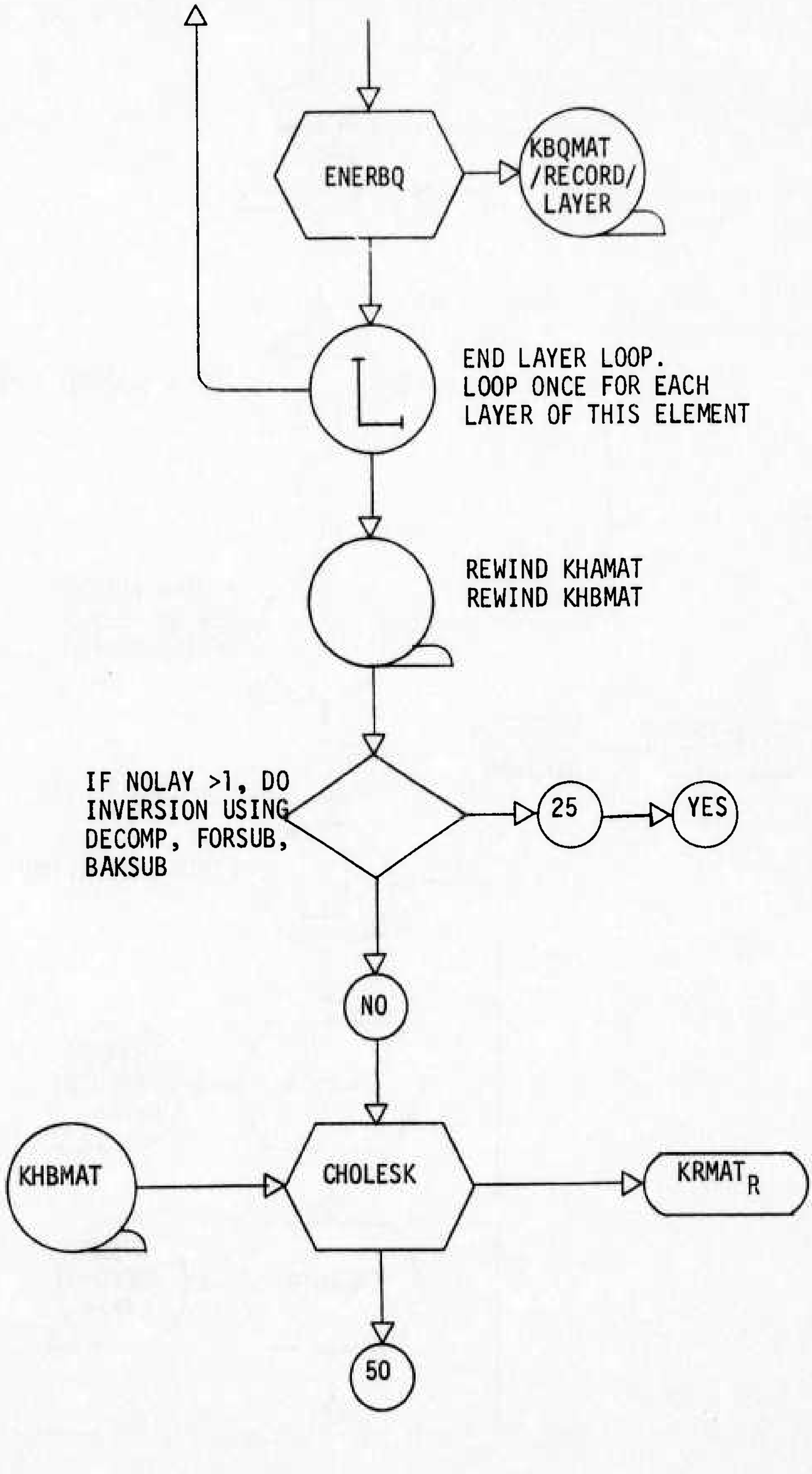
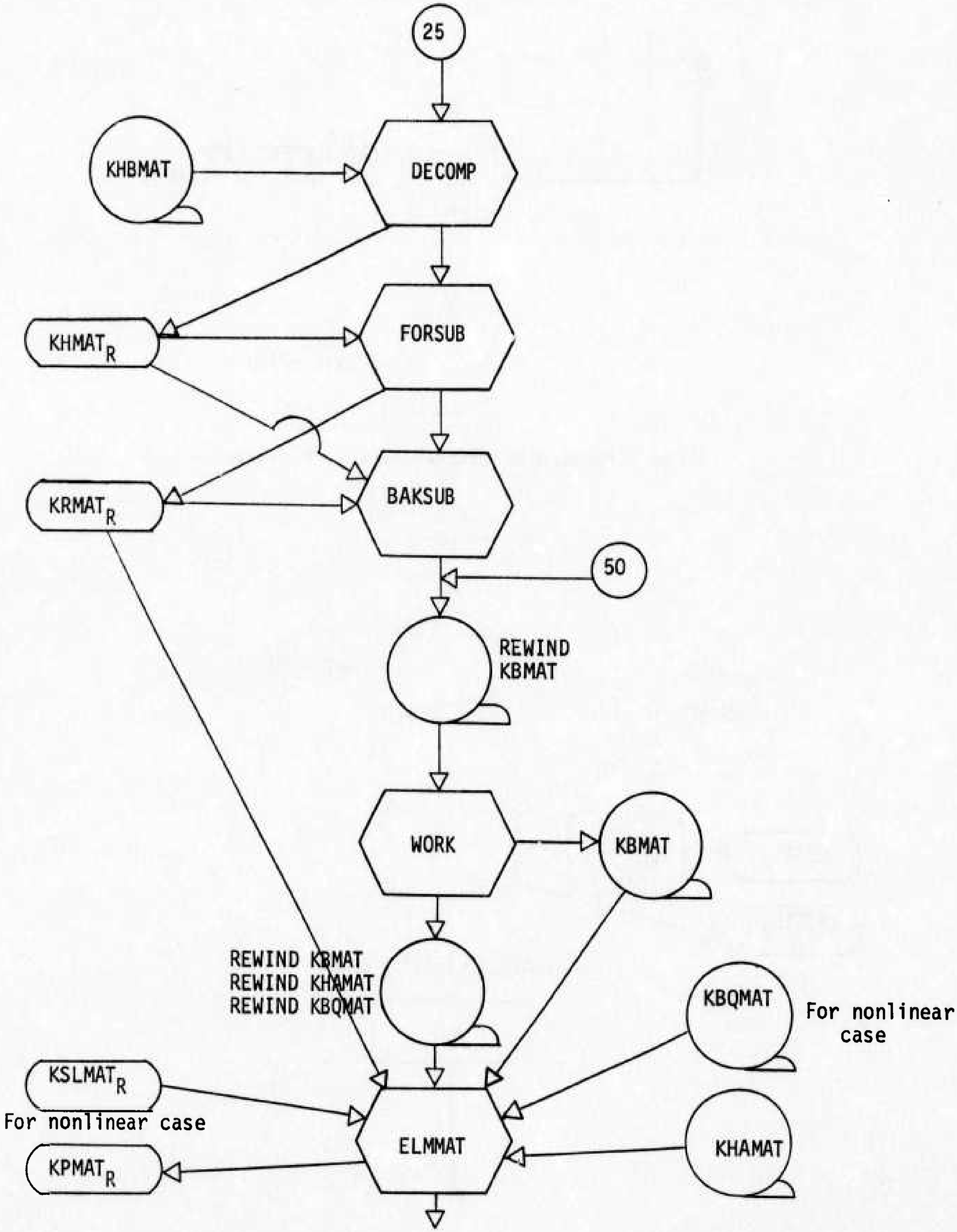
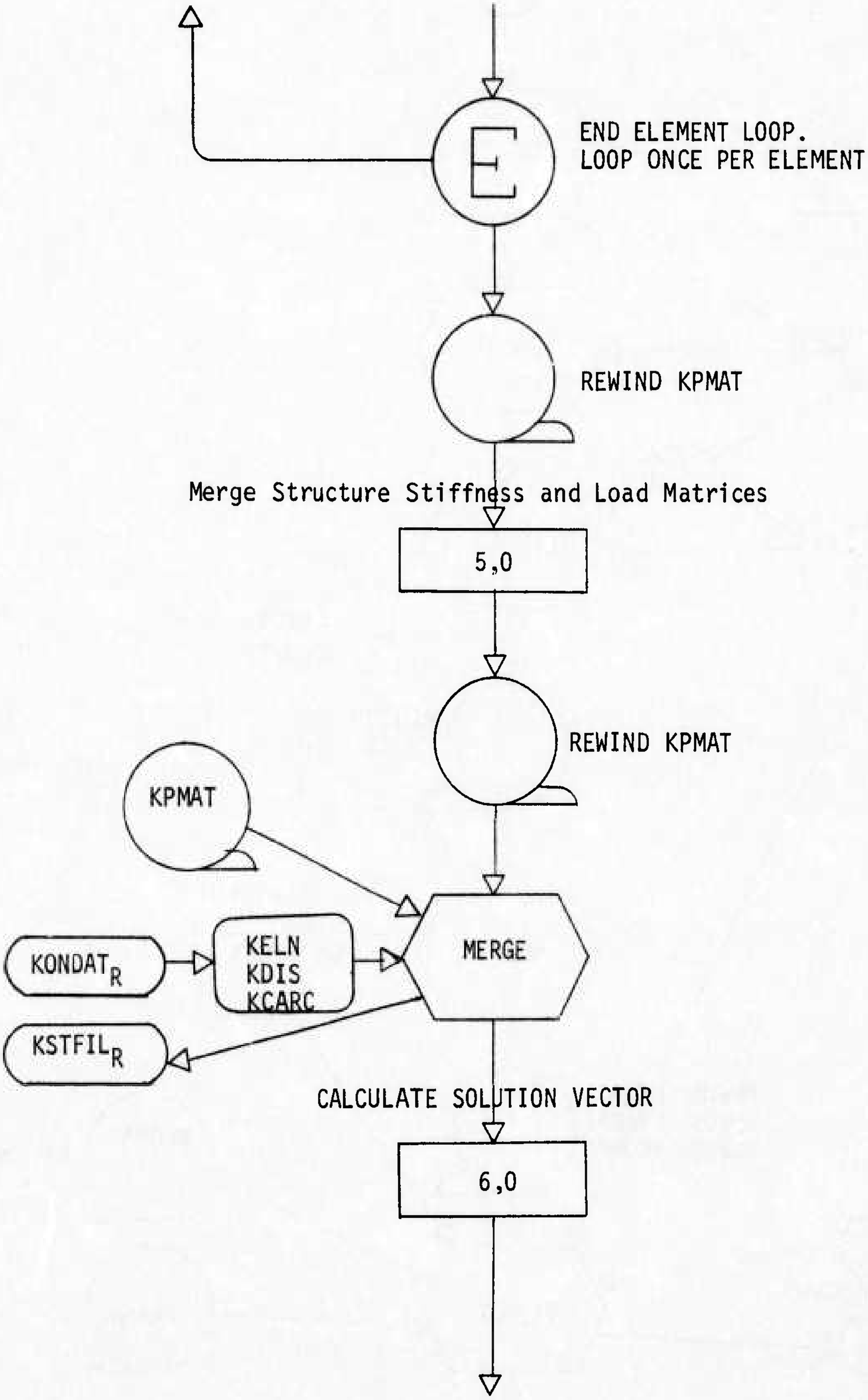


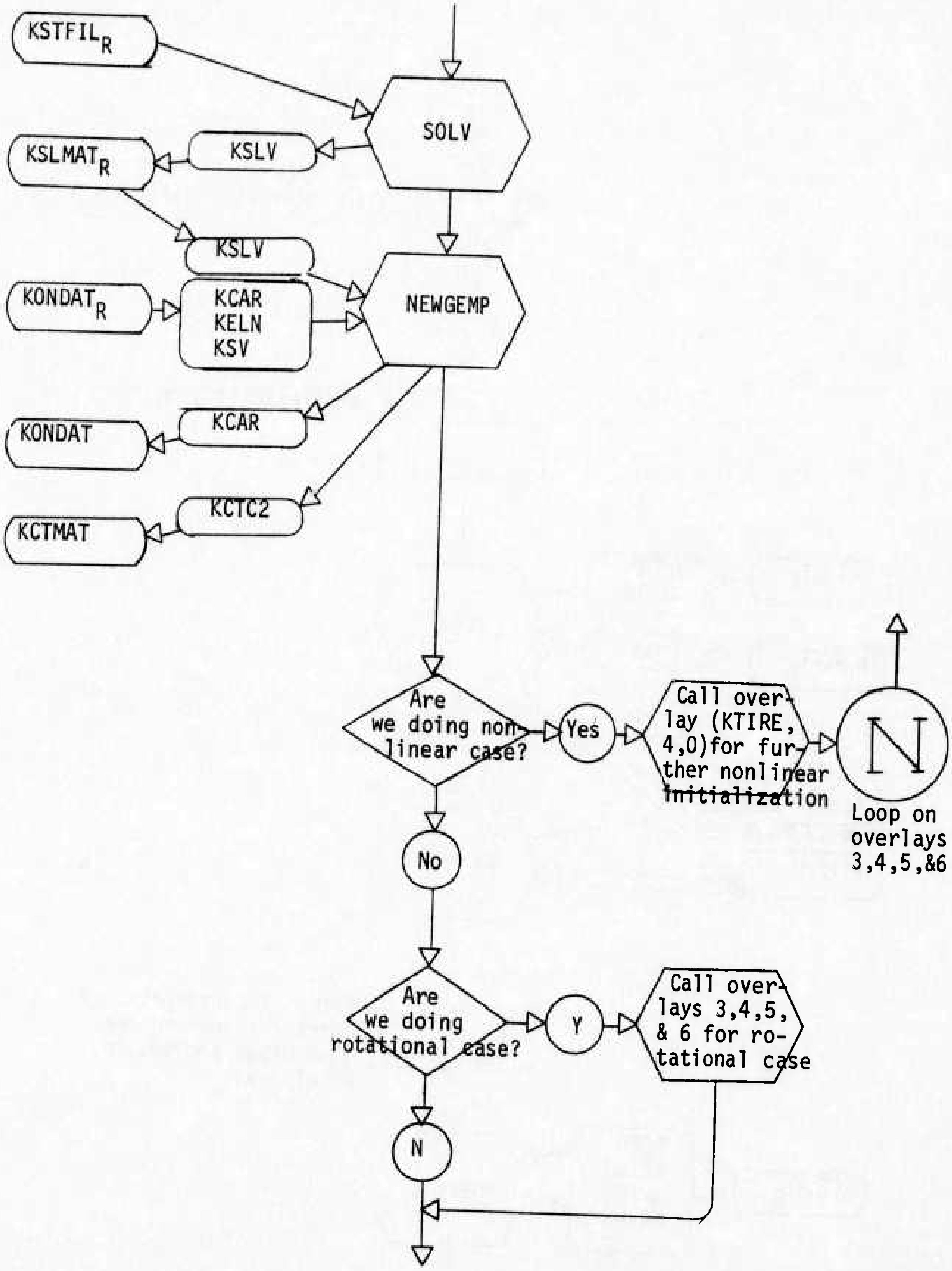
Table 4.

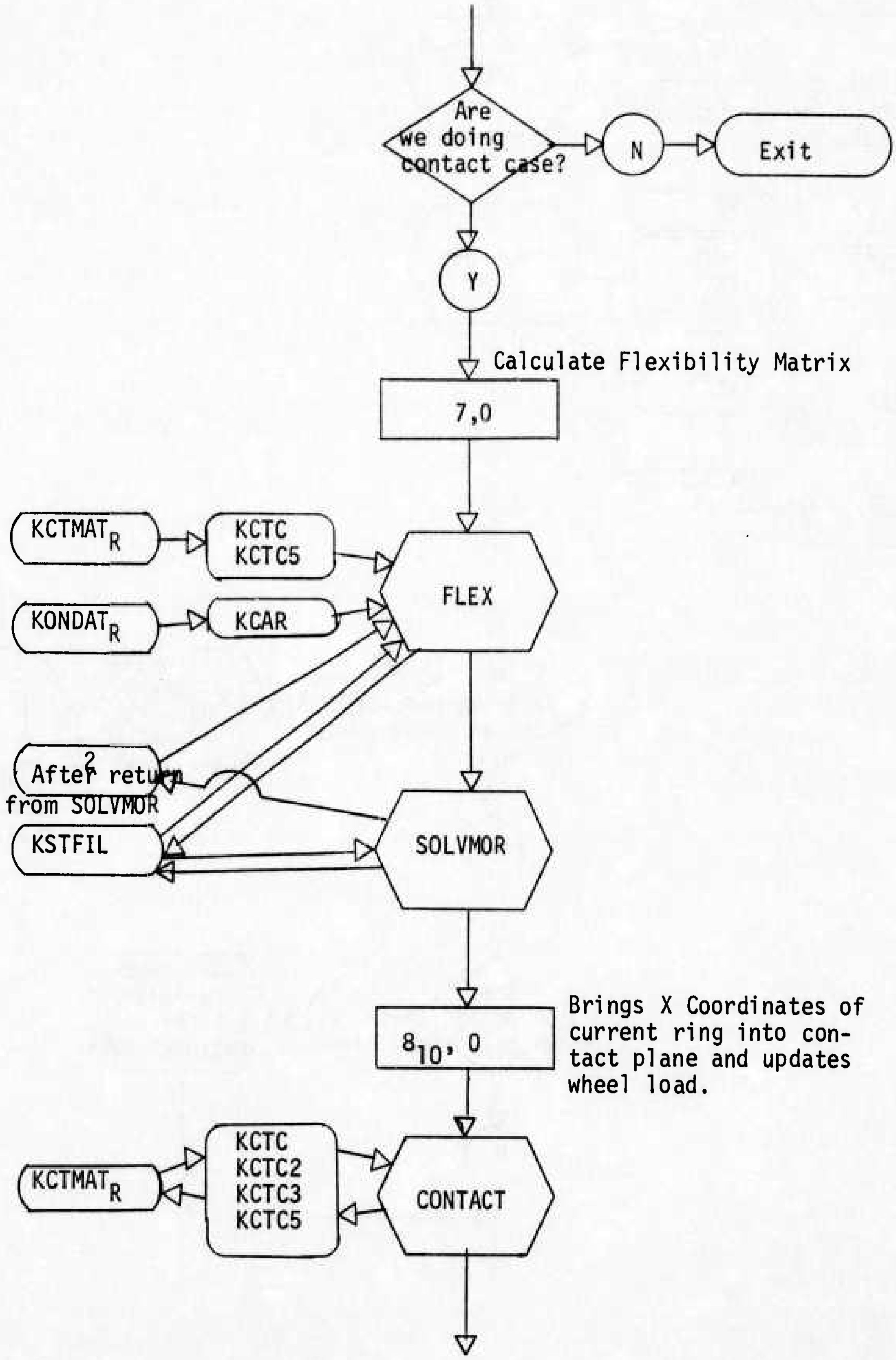

REWIND
KPMAT
E
BEGIN ELEMENT LOOP
REWIND KHAMAT
REWIND KHBMAT
REWIND KBQMAT
KLADAT R
NUMBERED
RECORDS
L
BEGIN LAYER LOOP
ENERGYA
KHAMAT
//RECORD/
LAYER
ENERGYB
KHBMAT
/RECORD/
LAYER

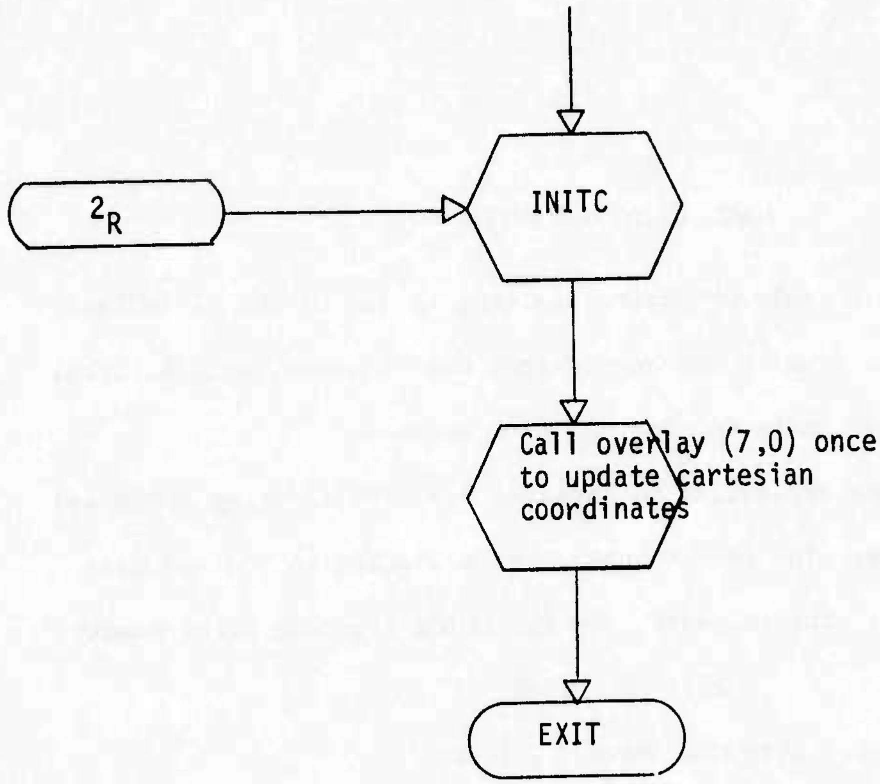

ENERBQ
KBQMAT /RECORD/ LAYER
END LAYER LOOP. LOOP ONCE FOR EACH LAYER OF THIS ELEMENT
REWIND KHAMAT
REWIND KHBMAT
IF NOLAY >1, DO INVERSION USING DECOMP, FORSUB, BAKSUB
25
YES
NO
KHBMAT
CHOLESK
$KRMAT_R$
50


25
KHBMAT
DECOMP
$KHMAT_R$
FORSUB
$KRMAT_R$
BAKSUB
50
REWIND
KBMAT
WORK
KBMAT
REWIND KBMAT
REWIND KHAMAT
REWIND KBQMAT
KBQMAT
For nonlinear
case
$KSLMAT_R$
For nonlinear case
ELMMAT
KHAMAT
$KPMAT_R$


END ELEMENT LOOP.
LOOP ONCE PER ELEMENT
REWIND KPMAT
Merge Structure Stiffness and Load Matrices
5,0
REWIND KPMAT
KPMAT
$KONDAT_R$
KELN
KDIS
KCARC
MERGE
$KSTFIL_R$
CALCULATE SOLUTION VECTOR
6,0


KSTFIL_R
SOLV
KSLMAT_R
KSLV
KSLV
KONDAT_R
KCAR
KELN
KSV
NEWGEMP
KONDAT
KCAR
KCTMAT
KCTC2
Are we doing nonlinear case?
Yes
Call overlay (KTIRE, 4,0)for further nonlinear initialization
N
Loop on overlays 3,4,5,&6
No
Are we doing rotational case?
Y
Call overlays 3,4,5, & 6 for rotational case
N


Are
we doing
contact case?
N
Exit
Y
Calculate Flexibility Matrix
7,0
KCTMAT$_R$
KCTC
KCTC5
FLEX
KONDAT$_R$
KCAR
2
After return
from SOLVMOR
KSTFIL
SOLVMOR
Brings X Coordinates of
current ring into con-
tact plane and updates
wheel load.
8_{10}, 0
KCTMAT$_R$
KCTC
KCTC2
KCTC3
KCTC5
CONTACT


INITC
2_R
Call overlay (7,0) once to update cartesian coordinates
EXIT

5. INPUT DATA PREPARATION

There are no inherent units assigned to any of the variables. Thus, the user is free to use any desired set; however, once defined, the units must be consistent for all parameters.

Format-free processing is employed for both floating point and integer variables. The current character manipulation routine does not allow blanks. For instance, the following floating point numbers

.1567 or -.1568

are not recognized. They must have the form

0.1568 or -0.1568

Numeric specifications must be separated from each other by at least one blank column. Thus the following format is accepted:

1. 0.5 0.2 -0.1

5.1 Title Cards

No restriction is imposed on the number of title cards. Each of these cards must start with a slash in column 1. Example:

```
/ DATA SET NUMBER 1
/ PREPARED 10/1/72
/ AIRCRAFT TIRE
/
```

5.2 Control Cards

A name is assigned to each of the control variables. The name is followed by the appropriate numerical specification. The last character on each of these cards must be the slash symbol, which is separated from the words or numeric specifications by any number of blank columns.

These control cards follow the schedule below:

BEGIN DATA INPUT /

BEGIN CONTROL PARAMETERS /

NODES N /

ELEMENTS E /

RADIUS R /

NRHO M /

NPRHO N /

LAYERS L /

GREEN α /

SPEED ω /

CONTACT Δ W /

NONLINEAR /

NORING NR /

NODMAX NM /

INCREMENTS IN /

END CONTROL PARAMETERS /

/

/

The above numeric control variables are defined as follows :

N = Number of nodes (integer)

E = Number of elements (integer)

R = Rotation radius

M = Number of curvefitting parameters for the median section (integer)

N = Number of prescribed data points for the meridian section (integer)

L = Maximum layer number (integer)

α = Green angle

ω = Rotational speed

Δ = Initial deflection for contact

NR = Number of rings

NM = Maximum number of nodes in a ring

IN = Number of increments for nonlinear inflation

W = Maximum wheel load

5.3 Nodal Data

The node number and the corresponding curvilinear coordinates are specified here.

BEGIN NODAL DATA /

i Θ ϕ

.

.

END NODAL DATA /

/

/

The numeric variables i, Θ, and ϕ are

i = Node number (integer)

Θ = Parallel in radians (floating p.)

ϕ = Meridian in radians (floating p.)

5.4 Element Data

There are three nodes associated with each surface element. The node assignments must follow the right-hand rule according to the outward normal direction. Furthermore, the first node number must be the smallest.

Within this record, the elastic constants are also specified for each layer within the element, in a principal reference frame. Thus,

BEGIN ELEMENT DATA /

E j N_1 N_2 N_3 N_4 /

L 1 t r E_R ν_R E_c ν_c b S_c S_R f /

.

.

.

L k t r E_R ν_R E_c ν_c b S_c S_R f /

END ELEMENT DATA /

The numeric characters in the above records are

j = Element number (integer)

N_1, N_2, N_3 = Node numbers, assigned according to the right-hand rule dictated by the outward normal (integer). N_1 must be the smallest.

N_4 = Total number of layers for this element.

k = Layer number (integer)

t = Layer thickness

r = cord versus matrix area fraction per inch

E_R = Matrix Young's Modulus

ν_R = Matrix Poisson Ratio

E_c = Cord Young's Modulus

ν_c = Cord Poisson Ration

b = Bias multiplier

S_R = Rubber mass density

S_c = Cord mass density

For identification purposes the letter E must precede the nodal information and the letter L must precede the layer flexibility information.

5.5 Prescribed Forces

At a given node one may specify three external force components. The input records read as

BEGIN FORCE DATA

k P_1 P_2 P_3

END FORCE DATA

/

/

where

k = Node number (integer)

P_i = Prescribed force components (floating p.)

In case of pressure loading the normal (third) component is assumed to follow the local normal to the element under consideration.

5.6 Prescribed Displacements

At each node the three rectilinear and two rotational displacement components may be restrained (i.e., equal to zero). These components

are referred to the base vectors of the undeformed reference surface and labeled according to the following schedule, for a rotationally symmetric problem:

q_1 = Component along the parallel

q_2 = Component along the meridian

q_3 = Component along the normal

q_4 = Rotation component along the parallel

q_5 = Rotation component along the meridian

The input records are exhibited as follows:

BEGIN DISPLACEMENT DATA /

k M N_1 N_2 ... N_M /

END DISPLACEMENT DATA /

where

k = Node number (integer)

M = Total number of displacements restrained at the node under consideration (integer)

$N_1, N_2, \ldots$ = The number of displacements being restrained (integer)

The contact problem is no longer rotationally symmetric, and since one is dealing with a load of fixed direction the rectilinear displacements are referred to the base vectors of a fixed cartesian frame, while the rotations are decomposed along the base vectors of the shell reference surface. Thus,

q_1 = Component along the x_1 axis

q_2 = Component along the x_2 axis

q_3 = Component along the x_3 axis

q_4 = Rotation components along the parallel

q_5 = Rotation component along the meridian

The input records are exhibited as follows:

BEGIN CARTESIAN DATA /

k M N_1 N_2 ... N_M /

where

k = Node number (integer)

M = Total number of displacements restrained at the node under consideration (integer)

N_1, N_2 ... = The number of displacements being restrained (integer)

5.7 <u>Curvefitting the Meridian Reference Surface</u>

The Cartesian coordinates of the meridian section are defined in this record. Thus,

BEGIN CURVEFIT RHOS /

i x_1 x_2 /

END CURVEFIT RHOS /

/

/

where

i = Sequence number of data points, (i = 1,2,... NPRHO), (integer).

x_1,x_2 = Cartesian coordinates (floating p.)

5.8 <u>Increment Data</u>

In this record the increment numbers with the corresponding

incremental pressure are defined as follows:

BEGIN INCREMENT DATA /

1 P_1 /

i P_i /

IN P_{IN} /

END INCREMENT DATA /

where

i = Increment number

P_i = Incremental pressure

5.9 Contact Data

The candidate nodes for contact are arranged in a ring-like fashion. For each ring one assigns the corresponding nodes as follows:

BEGIN CONTACT DATA /

1 1 1 /

I N_I M_1 M_2 $M_3 \ldots M_{N_I}$ /

END CONTACT DATA /

where

I = Ring number

N_I = Number of nodes in the ring

$M_1, M_2, \ldots M_{N_I}$ = The node numbers in the ring under consideration

5.10 Print Options

The output information is governed by the following control cards:

BEGIN PRINT OPTIONS /

ALL /

```
CONTROL PARAMETERS /
NODAL DATA /
ELEMENT DATA /
CURVEFIT RHOS /
LOCAL UNIT VECTORS /
NODAL OUTPUT TABLE /
INCREMENT DATA /
CONTACT DATA /
END PRINT OPTIONS /
/
/
END DATA INPUT /
```

5.11 Commenting the Input Records

Following the slash on the input data cards, comments may be inserted. These comments may be continued on any number of cards, having a slash for the first character. Thus,

```
.
.
.
BEGIN NODAL DATA /
1 0.5 0.8 -0.6 / UPDATED, NOV. 11, 1971
2 0.6 1.0 -0.5 / BERTRAND RUSSELL DESCRIBED
/ THE MATHEMATICIAN AS ONE WHO NEITHER KNOWS
/ WHAT HE IS TALKING ABOUT NOR CARES WHAT
/ HE SAYS IS TRUE.
3 0.8 2.0 0.5 /
.
.
.
```

```
BEGIN ELEMENT DATA  /
1  2  3  10  /  THE ENGINEER SOMETIMES
/  PRIDES HIMSELF ON BEING THE MAN WHO CAN DO
/  FOR A REASONABLE COST WHAT ANOTHER
/  WOULD EXPEND A FORTUNE ON, IF INDEED
/  HE COULD DO IT AT ALL.
2  4  5  11  /
.
.
.
```

5.12 Input Table Summary

The input data card set-up is summarized in this section

```
/  DATA SET NUMBER 1
/  PREPARED  10/1/72
/  AIRCRAFT TIRE
/
/
BEGIN DATA INPUT  /
BEGIN CONTROL PARAMETERS  /
NODES N  /
ELEMENTS E  /
RADIUS R  /
NRHO M  /
NPRHO  K  /
LAYERS L  /
END CONTROL PARAMETERS  /
```

/

/

BEGIN NODAL DATA

i Θ ϕ /

END NODAL DATA /

/

/

BEGIN ELEMENT DATA /

E j N_1 N_2 N_3 N_4 /

L k t r E_R ν_R E_c ν_c b S_c S_R f /

END ELEMENT DATA /

/

/

BEGIN FORCE DATA /

k P_1 P_2 P_3 /

END FORCE DATA /

/

/

BEGIN DISPLACEMENT DATA /

k M N_1 N_2 N_3 /

END DISPLACEMENT DATA /

/

/

BEGIN CARTESIAN DATA /

k M N_1 N_2 N_3 /

END CARTESIAN DATA /

```
/

/

BEGIN CURVEFIT RHOS /

i x1 x2

END CURVEFIT RHOS /

/

/

BEGIN CURVEFIT BETAS /

i x1 x2 /

END CURVEFIT BETAS /

/

/

BEGIN INCREMENT DATA /

I P /

END INCREMENT DATA /

/

/

BEGIN CONTACT DATA /

I N M1 M2 M3 /

END CONTACT DATA /

/

/

BEGIN PRINT OPTIONS /

ALL /

CONTROL PARAMETERS /
```

```
NODAL DATA  /
ELEMENT DATA  /
CURVEFIT RHOS  /
LOCAL UNIT VECTORS  /
NODAL OUTPUT TABLE  /
ELEMENT OUTPUT TABLE  /
END PRINT OPTIONS  /
/
/
END DATA INPUT
```

For future extension, the code angle variation may be described by experimental data points. This phase of the code is not yet implemented, however, as the corresponding input data must be present. Thus, augment the control parameter block by

```
NBETA 2  /
NPBETA 2  /
```

6. OUTPUT DESCRIPTION

During the data processing phase, associated with geometrical characterization, the user may exercise the print options described in Section 5. The corresponding output information contains the following records:

- Input Data
  The user's input is listed. To each card image a record number and a card sequence number are assigned for error detection purposes.
- Control Parameters
- Curvelinear Coordinates of the Nodes
- Element and Layer Data
- Cartesian Coordinates of the Data Points of the Reference Meridian
- Contact Candidate Nodes
- Increment Data for Nonlinear Inflation
- Nodal Output Table
- Element Output Table
- Local Unit Vectors

The ouput table of the actual execution phase is not yet formalized. Currently, only the generalized displacements are printed with the element membrane stresses during the incremental inflation process and tire rotation. After each step the geometry is updated and thus the Element Output Table and Local Unit Vectors Table is recalculated. For the contact problem, the nodal contact forces are

printed at each itemation followed by the total nodal contact forces and the final geometrical configuration:

- Intermediate Nodal Contact Forces carrying the title of Solution Matrix
- Final Contact Forces carrying the title of Contact Forces
- Final node positions in a rectangular cartesian and cylindrical coordinate system

Thus, the code is yet to be implemented by a complete output module to allow the analyst to select elements of design interest for stress and strain calculation purposes.

7. ERROR EXITS

Extensive input error checks are provided in the data preparation phase. Each input card is traced according to its sequence number in the input deck. For cross reference, appropriate record numbers (Nodal Data, for instance) are also assigned to the input cards.

Consider for instance an erroneous card in the Element Data (Record 31, say) where identical node numbers are assigned to distinct nodes:

```
E 1 1 2 2 2 /
```

The error message reads:

```
RECORD 31) E 1 1 2 2 2 / CARD 43
           IN THE ABOVE ELEMENT CARD, TWO OR MORE OF THE
           ELEMENT NODES ARE EQUAL. ELEMENT DEFINITION IGNORED
```

Errors of this nature are summarized at the end of the data processing phase. For the user's convenience, an input data set is being constructed which will contain all possible logical errors with the appropriate error diagnostic.

8. TIMING AND STORAGE

For large problems it is important to estimate the needed execution time for both central processor and peripherial operations. At this time not enough data is available to either construct appropriate formulas in terms of major computational parameters or graphs based on direct experiemtation. On the CDC 6600 machine at the WPAFB under the RUN system the central processor time may be estimated according to the formula

$$CP \text{ (minutes)} = 10^{-3} * (E * L * S)$$

where

E = Number of elements

L = Number of layers

S = Number of steps for incremental inflation.

For large problems the peripherial time is roughly that required by the central processor.

The program does not yet contain output information for minimum execution field length requirements during the loading phase. If the declared field length is too small for execution, an allocation error message will appear at the corresponding phase of the code. Because of the size of the fourth overlay, substantial storage is required even for small (50 elements) problems, such as 120,000 central memory in octals. The largest test case (200 elements) required 135,000 central memory in octals.

9. SAMPLE INPUT

In this section a pathological example is considered to demonstrate the structure of the input data which covers all phases of the computer code.

The problem under consideration is the inflation, rotation, and contact of a strip along the meridian of a toroidal shell shown by Figure 1. It is assumed that the strip is of uniform thickness consisting of two layers. The cord angle varies along the meridian according to the classical lift equation [1]. The input set listed below is annotated for clarity in presentation.

```
/        NONLINEAR STRIP
/
/
/
/
/
CHECKOUT  /  TURNS ON PRINTS OF ROUTINES NAMES
/
/
BEGIN DATA INPUT  /
BEGIN CONTROL PARAMETERS  /    NO PARTICULAR ORDER IS ASSIGNED
 ELEMENTS  12  /
 NODES  11  /
 RADIUS  9.15  /
 NRHO  10  /
 NPRHO  27  /
 NPETA 2  /        NOT ACTIVE, BUT MUST BE PRESENT
 NPBETA 2  /       NOT ACTIVE, BUT MUST BE PRESENT
 LAYERS 2  /
 GREEN  0.95  /
 SPEED  100.  /
 NONLINEAR /
 INCREMENTS  5  /
CONTACT -0.05  5000.  /   WHEEL LOAD IS NOT ACTIVE
NORING  3  /
NODMAX  3  /
 END CONTROL PARAMETERS  /
BEGIN NODAL DATA  /
 1  0.  0.  /    GIVEN IN RADIANS
 2  0.02  0.  /
 3  0.01  0.056  /
  4  0.  0.112  /
  5  0.02  0.112  /
  6  0.01  0.168  /
  7  0.  0.224  /
  8  0.02  0.224  /
  9  0.01  0.28  /
  10  0.  0.336  /
  11  0.02  0.336  /
END NODAL DATA  /
/
/
BEGIN ELEMENT DATA  /
  E  1  1  2  3  2  /
 L 1 0.0645 0.455 450. 0.49 156000. 0.7 1. 0.0001 0.0001 0.  /
 L 2 0.0645 0.455 450. 0.49 156000. 0.7 -1. 0.0001 0.0001 0.  /
  E  2  2  5  3  2  /
 L 1 0.0645 0.455 450. 0.49 156000. 0.7 1. 0.0001 0.0001 0.  /
 L 2 0.0645 0.455 450. 0.49 156000. 0.7 -1. 0.0001 0.0001 0.  /
 E  3  1  3  4  2  /
 L 1 0.0645 0.455 450. 0.49 156000. 0.7 1. 0.0001 0.0001 0.  /
 L 2 0.0645 0.455 450. 0.49 156000. 0.7 -1. 0.0001 0.0001 0.  /
  E  4  3  5  4  2  /
 L 1 0.0645 0.455 450. 0.49 156000. 0.7 1. 0.0001 0.0001 0.  /
 L 2 0.0645 0.455 450. 0.49 156000. 0.7 -1. 0.0001 0.0001 0.  /
  E  5  4  5  6  2  /
```

```
L 1 0.0645 0.455 450. 0.49 156000. 0.7 1. 0.0001 0.0001 0.  /
L 2 0.0645 0.455 450. 0.49 156000. 0.7 -1. 0.0001 0.0001 0.  /
 E  6  5  8  6  2  /
L 1 0.0645 0.455 450. 0.49 156000. 0.7 1. 0.0001 0.0001 0.  /
L 2 0.0645 0.455 450. 0.49 156000. 0.7 -1. 0.0001 0.0001 0.  /
 E  7  4  6  7  2  /
L 1 0.0645 0.455 450. 0.49 156000. 0.7 1. 0.0001 0.0001 0.  /
L 2 0.0645 0.455 450. 0.49 156000. 0.7 -1. 0.0001 0.0001 0.  /
 E  8  6  8  7  2   /
L 1 0.0645 0.455 450. 0.49 156000. 0.7 1. 0.0001 0.0001 0.  /
L 2 0.0645 0.455 450. 0.49 156000. 0.7 -1. 0.0001 0.0001 0.  /
 E  9  7  8  9  2  /
L 1 0.0645 0.455 450. 0.49 156000. 0.7 1. 0.0001 0.0001 0.  /
L 2 0.0645 0.455 450. 0.49 156000. 0.7 -1. 0.0001 0.0001 0.  /
 E  10  8  11  9  2  /
L 1 0.0645 0.455 450. 0.49 156000. 0.7 1. 0.0001 0.0001 0.  /
L 2 0.0645 0.455 450. 0.49 156000. 0.7 -1. 0.0001 0.0001 0.  /
 E  11  7  9  10  2  /
L 1 0.0645 0.455 450. 0.49 156000. 0.7 1. 0.0001-0.0001 0.  /
L 2 0.0645 0.455 450. 0.49 156000. 0.7 -1. 0.0001 0.0001 0.  /
 E  12  9  11  10  2  /
L 1 0.0645 0.455 450. 0.49 156000. 0.7 1. 0.0001 0.0001 0.  /
L 2 0.0645 0.455 450. 0.49 156000. 0.7 -1. 0.0001 0.0001 0.  /
END ELEMENT DATA  /
/
/
BEGIN FORCE DATA  /
  1  0.  0.  1.  /    NOT ACTIVE BUT MUST BE PRESENT
  2  0.  0.  1.  /    SEE PRESF SUBROUTINE FOR CONCENTRATED LOADS
  3  0.  0.  1.  /
  4  0.  0.  1.  /
  5  0.  0.  1.  /
  6  0.  0.  1.  /
  7  0.  0.  1.  /
  8  0.  0.  1.  /
  9  0.  0.  1.  /
  10  0.  0.  1.  /
  11  0.  0.  1.  /
END FORCE DATA  /
/
/
BEGIN DISPLACEMENT DATA  /
    1    5    1    2    3    4    5    /  FIXED
    2    5    1    2    3    4    5    /  FIXED
  3  2  1  5  /  ZERO PARALLEL DISPLACEMENT AND MERIDIAN ROTATION
  4  2  1  5  /
  5  2  1  5  /
  6  2  1  5  /
  7  2  1  5  /
  8  2  1  5  /
  9  2  1  5  /
   10    5    1    2    3    4    5    /
   11    5    1    2    3    4    5    /
END DISPLACEMENT DATA  /
/
/
```

```
BEGIN CARTESIAN DATA /
    1    5    1    2    3    4    5    / FIXED
    2    5    1    2    3    4    5    / FIXED
    3    2    2    5    /  ZERO Y-DISPLACEMENT/MERIDIAN ROTATION
    4    2    2    5    /
    5    2    2    5    /
    6    2    2    5    /
    7    2    2    5    /
    8    2    2    5    /
    9    2    2    5    /
   10    5    1    2    3    4    5    /
   11    5    1    2    3    4    5    /
END CARTESIAN DATA /
/
/
BEGIN CURVEFIT RHOS  /
  1  4.69  0.  /
  2  4.68  0.37  /
  3  4.66  0.74  /
  4  4.63  1.1  /
  5  4.58  1.47  /
  6  4.51  1.94  /
  7  4.4  2.19  /
  8  4.25  2.52  /
  9  4.05  2.84  /
   10  3.83  3.13  /
   11  3.57  3.39  /
   12  3.29  3.62  /
   13  2.97  3.81  /
   14  2.63  3.95  /
   15  2.29  4.03  /
   16  1.89  4.04  /
   17  1.52  3.97  /
   18  1.16  3.88  /
   19  0.82  3.73  /
   20  0.5  3.55  /
   21  0.18  3.35  /
   22  0.  3.24  /
   23  -0.25  3.1  /   FICTICIOUS POINTS TO AVOID OSCILLATION
   24  -0.425  3.0  /
   25  -0.6  2.9  /
   26  -0.75  2.8  /
   27  -0.95  2.7  /
 END CURVFIT RHOS  /
 /
 /
  BEGIN INCREMENT DATA /
  1   2.  /
  2   2.  /
  3   2.  /
  4 10.  /
  5 20.  /
 END INCREMENT DATA /
 /
 /
 BEGIN CURVFIT BETAS  /
```

```
  1  1.  2.  /        NOT ACTIVE, BUT MUST BE PRESENT
  2  1.  2.  /        NOT ACTIVE, BUT MUST BE PRESENT
END CURVFIT BETAS  /
/
/
BEGIN CONTACT DATA  /
  1  1  1  /          THE FIRST CONTACT NODE MUST BE LABELLED  1
  2  3  2  3  4  /
  3  2  5  6  /
END CONTACT DATA  /
/
/
BEGIN PRINT OPTIONS  /
CONTROL PARAMETERS  /
NODAL DATA  /
ELEMENT DATA  /
CURVFIT RHOS  /
CURVFIT BETAS  /
LOCAL UNIT VECTORS  /
NODAL OUTPUT TABLE  /
INCREMENT DATA /
ELEMENT OUTPUT TABLE  /
END PRINT OPTIONS  /
/
/
END DATA INPUT  /
```

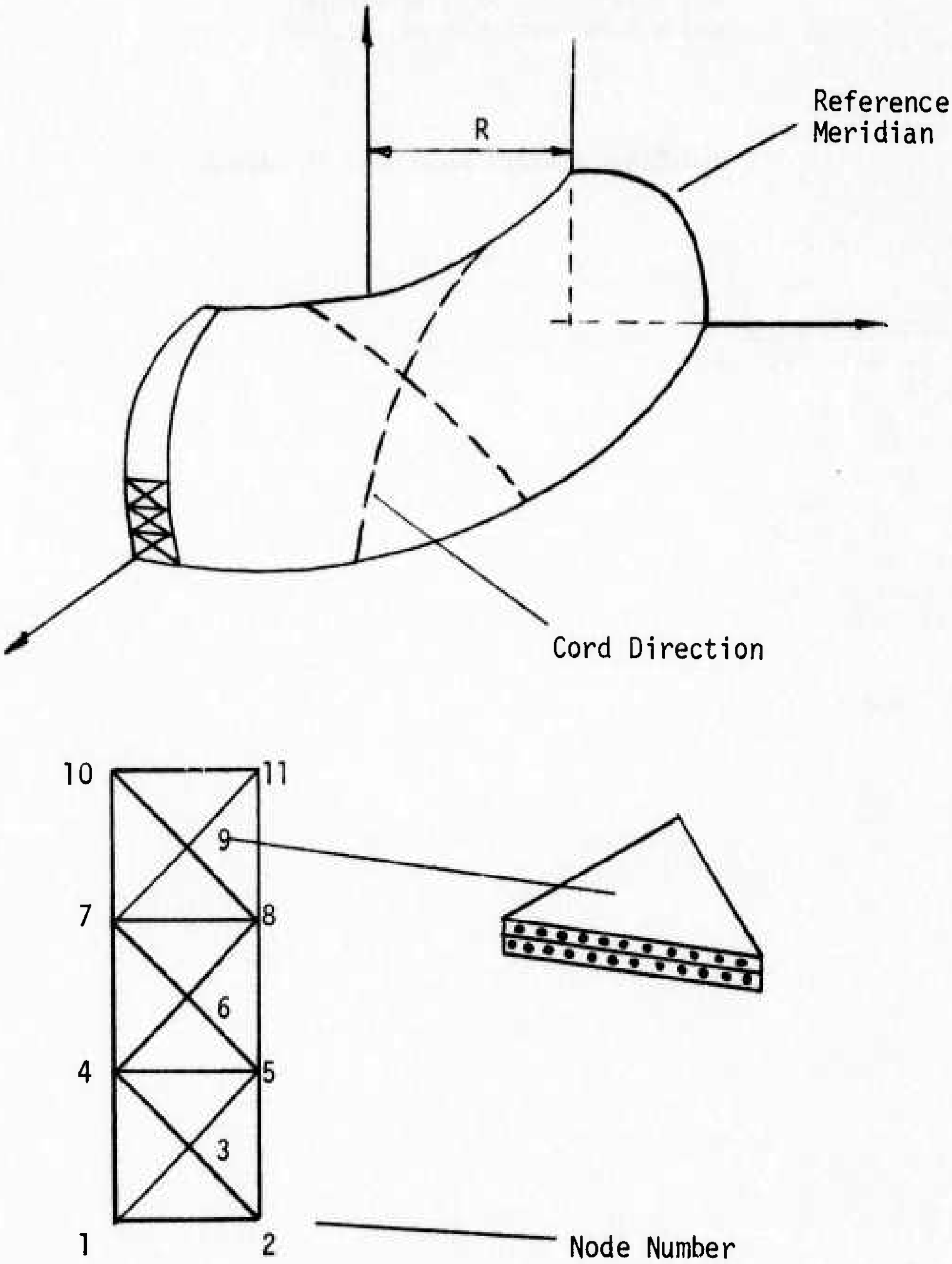


Figure 1. Geometrical Characterization for Sample Input Set

10. PROGRAM LISTING

The Load Map presented below was generated on a CDC-6600 machine using the RUN compiler at the Wright-Patterson Air Force Base installation. The corresponding program listing is available upon request for qualified applicants.

```
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$

CORE MAP  20.12.46.  OVERLAY    00.00    CONTROL                                          000100     033443     000000     000000
          ---TIME---LOAD MODE --L1--L2-----TYPE--------------USER---++---CALL-------------FWA LOAD--LWA LOAD--BLNK COMN--LENGTH--
          FWA LOADER  123767  FWA TABLES  121214
          -PROGRAM----ADDRESS-                    --LABELED---COMMON--
          TIRE         001417                               BCINDEX       000101
                                                            CONST1        000475
                                                            CUBAT         000477
                                                            CONST         000544
                                                            ERROR         000550
                                                            FILES         000717
                                                            KADINV        000733
                                                            KHAD          001041
                                                            PRINTS        001174
                                                            RECORD        001233
                                                            SIZE          001262
                                                            RETRIV        001300
                                                            MATSIZ        001313
                                                            TQDISP        001324
                                                            INSTRS        001401
                                                            CONTACT       001404
          MATPRT       025047
          MATSUB       025164
          MATMPY       025217
          MATADD       025234
          MATSMP       025251
          MATNEG       025267
          MATRAN       025317
          ERRSET       025525                               ERROR         000550
                                                            INDTA         025355
          ERRSUM       025544                               ERROR         000550
          INPROS       025645
          VECADO       025671
          VECMAT       025722
          VECMUL       025751
          VECSUB       026007
          ALOCATE      026040                               BCINDEX       000101
          KFL          026460
          MSTG         026503
          SSZERO       026514
          CPC          026527
          INITMS       026777
          LOCF         027117
          SYSTEM       027122                               SCOPE2        027122
          OVERLAY      030226
          OUTPTC       030331
          OVERLOD      030423
          GETBA        030471
          KODER        030510
          SIO$         031772
```

```
--ENTRY-----ADDRESS-                                    REFERENCES
TIRE        001420
MATPRT      025050
MATSUB      025165
MATMPY      025217
MATADD      025235
MATSMP      025252
MATNEG      025270
MATRAN      025320
ERRSET      025526
ERRSUM      025545
INPRDS      025646
VECADD      025672
VECMAT      025723
VECMUL      025752
VECSUB      026010
ALOCATE     026041
OPNCORE     026051
OEFPOS      026125
CLRPOS      026221
KFL         026460          ALOCATE    026074

MSTG        026503          ALOCATE    026337

SSZERO      026514          ALOCATE    026121    026350

CPC         026575          KFL        026464

CPC02       026654
CPC03       026527
CPC04       026546
CPC999      026767
OPENMS      027001          TIRE       001424    001427    001432    001435    001440    001443    001446
                                       001451

STINDX      027053
LOCF        027120          ALOCATE    026067

XLOCF       027120
Q8NTRY      027123          TIRE       001421

SYSTEM      027330          INITMS     027023    027013
                            OVERLAY    030312
                            OUTPTC     030410
                            KODER      031576

SYSTEMC     027274
SYSTEMP     027323
END         027217          TIRE       001602
                            MATPRT     025132
```

		MATSUB	025206							
		MATRAN	025344							
		ERRSUM	025574							
		VECMUL	025775							
		ALOCATE	026363							
STOP	027247	TIRE	001600							
		ERRSUM	025572							
		ALOCATE	026361							
EXIT	027241									
ABNORML	027257	INITMS	027014							
		OVERLAY	030313							
		OUTPTC	030411							
		KOOER	031577							
OVERLAY	030227	TIRE	001457	001465	001477	001511	001522	001540	001552	
			001555	001563	001566	001576				
OUTPTC	030333	MATPRT	025057	025061	025063	025065	025066	025074	025076	
			025077	025102	025117	025123				
		ERRSUM	025550	025552	025554	025555	025560	025564	025570	
		ALOCATE	026354	026356	026357					
OVERLOD	030423	OVERLAY	030270							
GETBA	030472	INITMS	027004	027056						
		SIO$	032255							
KOOER	030511	OUTPTC	030352	030335						
CIO1.	033065									
RCL1.	033076	SYSTEM	027565							
DAT.	031774	OUTPTC	030347	030362	030370					
SIO.CTL	032222	SYSTEM	027556	027542						
INITL.	032253	SYSTEM	027502	027540						
		OUTPTC	030342							
SIO.	032321	SYSTEM	027504							
		OUTPTC	030367							
SIO.END	033040	SYSTEM	027555							
OPEN.	033104	INITMS	027036							
		SYSTEM	027662							
RDPRU.	033170									
BKSPRU.	033210	SYSTEM	027562							

```
AOVIN.      033220          SYSTEM      027554

POSFI.      033246
MVWOS.      033411
SYSERR.     033422
----UNSATISFIED EXTERNALS-----                              REFERENCES
```

```
CORE MAP  20.12.55.  OVERLAY    01.00    CONTROL                                                      033443     045070     045067     000001
          ---TIME---LOAO MOOE --L1--L2-----TYPE---------------USER---++---CALL-------------FWA LOAO--LWA LOAO--BLNK COMN--LENGTH--
          FWA LOAOER  123767  FWA TABLES  117061
          -PROGRAM----AOORESS-                          --LABELED---COMMON--
          INPUTD      033444                                      CONTACT      001404
```

		RCINDEX	000101
		ERROR	000550
		FILES	000717
		INDTA	025355
		KHAD	001041
		KADINV	000733
		PRINTS	001174
		RECORD	001233
		SIZE	001262
		RETRIV	001300
NODAT	035110	ERROR	000550
		FILES	000717
		INDTA	025355
		PRINTS	001174
		RECORD	001233
ELMDAT	035247	ERROR	000550
		FILES	000717
		INDTA	025355
		PRINTS	001174
		RECORD	001233
		SIZE	001262
FRCEDAT	035773	ERROR	000550
		FILES	000717
		INDTA	025355
		PRINTS	001174
		RECORD	001233
DISPDAT	036130	ERROR	000550
		FILES	000717
		INDTA	025355
		PRINTS	001174
		RECORD	001233
RHODAT	036402	ERROR	000550
		FILES	000717
		INDTA	025355
		PRINTS	001174
		RECORD	001233
BETADAT	036536	ERROR	000550
		FILES	000717
		INDTA	025355
		PRINTS	001174
		RECORD	001233
PRINDAT	036672	ERROR	000550
		INDTA	025355
		PRINTS	001174
RNDDAT	037220	ERROR	000550
		FILES	000717
		INDTA	025355
		PRINTS	001174
		RECORD	001233

```
INCRDAT    037506                          FILES     000717
                                           RECORD    001233
                                           INDTA     025355
                                           ERROR     000550
                                           PRINTS    001174
PINCR      037651                          PRINTS    001174
PCB        037775                          PRINTS    001174
PCP        040126                          CONTACT   001404
                                           SIZE      001262
PCRHO      040423                          PRINTS    001174
PDISP      040554                          PRINTS    001174
PEO        040705                          FILES     000717
                                           PRINTS    001174
                                           RECORD    001233
PFD        041114                          PRINTS    001174
PNO        041241                          PRINTS    001174
PRN        041375                          PRINTS    001174
WRDCHK     041540                          ERROR     000550
                                           INDTA     025355
INSERT     041603                          ERROR     000550
                                           INDTA     025355
RANGE      041666                          ERRCR     000550
COMPCHK    041765                          ERROR     000550
SETADD     042050                          KHAD      001041
                                           KADINV    000733
INIT       042205                          CONST     000544
                                           CONST1    000475
                                           CUBAT     000477
READREC    042550                          INDTA     025355
                                           INITSW    042545
                                           WOROS     042546
FMTERR     043205                          INDTA     025355
                                           WOROS     042546
GET        043251
PUT        043266
STRMOV     043302
INPUTS     043364
READMS     043446
INPUTC     043601
WRITMS     043722
KRAKER     044023
--ENTRY-----ADDRESS-                                     REFERENCES
INPUTD     033445
NODAT      035111          INPUTD     034231

ELMOAT     035250          INPUTD     034254

FRCEOAT    035774          INPUTD     034272

OISPOAT    036131          INPUTO     034300
```

RHODAT	036403	INPUTD	034313							
BETADAT	036537	INPUTD	034327							
PRINDAT	036673	INPUTD	034333							
RNDDAT	037221	INPUTD	034346							
INCRDAT	037507	INPUTD	034362							
PINCR	037652	INPUTD	034453							
PCB	037776	INPUTD	034431							
PCP	040127	INPUTD	034054	034372						
PCRHD	040424	INPUTD	034424							
PDISP	040555	INPUTD	034417							
PED	040706	INPUTD	034405							
PFD	041115	INPUTD	034412							
PND	041242	INPUTD	034377							
PRN	041376	INPUTD	034442							
WRDCHK	041541	INPUTD	033562	033606	034140					
		NODAT	035133							
		ELMDAT	035301	035516						
		FRCEDAT	036016	036060						
		DISPDAT	036172	036307						
		RHODAT	036421							
		BETADAT	036555							
		PRINDAT	036714	036722	036735	036750	036756	036764	036772	
			037000	037005	037021	037034	037047	037062	037075	
		RNDDAT	037366	037415						
		INCRDAT	037603							
INSERT	041604	INPUTD	033703	033707	033713	033717	033723	033727	033733	
			033737	033747	033752	033756	033762	033766	033772	
			033776							
		NODAT	035141	035162	035174					
		ELMDAT	035326	035356	035437	035521	035551			
		FRCEDAT	036021	036045						

		DISPDAT	036154	036175	036226					
		RHODAT	036430	036451	036463					
		BETADAT	036564	036605	036617					
		RNDDAT	037273	037323	037403					
		INCRDAT	037545	037572						
RANGE	041667	NODAT	035150							
		ELMDAT	035336	035375	035447	035531				
		FRCEDAT	036030							
		DISPDAT	036163	036204	036242					
		RHODAT	036437							
		BETADAT	036573							
		RNDDAT	037307	037343						
		INCRDAT	037560							
COMPCHK	041766	NODAT	035206							
		ELMDAT	035570	035613						
		FRCEDAT	036064							
		RHODAT	036475							
		BETADAT	036631							
		RNDDAT	037423							
		INCRDAT	037607							
SETADD	042051	INPUTD	033453							
INIT	042206	INPUTD	033454							
READREC	042551	INPUTD	033550	033560	033604	033630	034136	034152	034215
		NODAT	035125							
		ELMDAT	035272	035313	035477					
		FRCEDAT	036010							
		DISPDAT	036145							
		RHODAT	036417							
		BETADAT	036553							
		PRINDAT	036702							
		RNDDAT	037256							
		INCRDAT	037532							
FMTERR	043206	READREC	042556							
GET	043252	READREC	042632	042662	042724	043043				
PUT	043267	READREC	042653							
STRMOV	043303	READREC	042746							
INPUTS	043366	READREC	042751	042753	042755	042756	042764	042766	042770
			042771							
READMS	043447	PED	040762							

```
INPUTC    043603      READREC   042577   042601   042602   043022   043024   043025

WRITMS    043723      NODAT     035215
                      ELMDAT    035602   035625
                      FRCEDAT   036074
                      DISPDAT   036316   036324
                      RHODAT    036504
                      BETADAT   036640
                      RNODAT    037436   037445
                      INCRDAT   037616

KRAKER    044024      INPUTS    043371   043407
                      INPUTC    043636   043607

----UNSATISFIED EXTERNALS-----                   REFERENCES
```

```
                                                                                         033443    037016    037015    000001
CORE MAP  20.13.01.  OVERLAY    02.00    CONTROL
          ---TIME---LOAD MODE --L1--L2-----TYPE---------------USER---++---CALL-------------FWA LOAD--LWA LOAD--BLNK COMN--LENGTH--
          FWA LOADER  123767  FWA TABLES  120530
          -PROGRAM----ADDRESS-                     --LABELED---COMMON--
          NODCALC     033444                                BCINDEX     000101
                                                            FILES       000717
                                                            PRINTS      001174
                                                            RECORD      001233
                                                            SIZE        001262
                                                            RETRIV      001300
                                                            CONTACT     001404

          FITING      034070                                FILES       000717
                                                            PRINTS      001174
          LINSYS      034337                                PRINTS      001174
          CCAVEC      035131                                FILES       000717
                                                            PRINTS      001174
                                                            RECORD      001233
                                                            SIZE        001262
                                                            PRINTS      001174
          PNOT        035552                                PRINTS      001174
          PCRES       036116
          ACGOER      036247
          SINCOS      036261
          SQRT        036360
          ASINCOS     036423
          READMS      036561
          WRITMS      036714                                        REFERENCES
          --ENTRY-----ADDRESS-
          NODCALC     033445
          FITING      034074        NODCALC     033633    033640    033657    033664

          LINSYS      034340        FITING      034270

          CCAVEC      035136        NODCALC     033707    033717

          PNOT        035555        NODCALC     033733    033740
```

```
PCRES        036117           NODCALC     033645    033671

ACGOER       036250           LINSYS      034530    034676

SIN          036262           CCAVEC      035202    035206    035302

COS          036265           FITING      034172
                              CCAVEC      035164    035200    035204    035222

SQRT         036361           FITING      034134
                              CCAVEC      035327

ASIN         036427
ACOS         036424           FITING      034146
                              CCAVEC      035252

REAOMS       036562           FITING      034121
                              CCAVEC      035162

WRITMS       036715           CCAVEC      035427    035435    035441

----UNSATISFIED EXTERNALS-----                                REFERENCES
```



```
CORE MAP  20.13.04.  OVERLAY    03.00    CONTROL                                                   033443     036020     036017     000001
      ---TIME---LOAO MODE --L1--L2-----TYPE---------------USER---++---CALL-------------FWA LOAD--LWA LOAO--BLNK CGMN--LENGTH--
      FWA LOAOER  123767  FWA TABLES  120724
      -PROGRAM----AOORESS-                      --LABELED---COMMON--
      ELMCALC      033444                                BCINDEX      000101
                                                         ERROR        000550
                                                         FILES        000717
                                                         PRINTS       001174
                                                         RECORO       001233
                                                         RETRIV       001300
                                                         SIZE         001262

      ALUVC        033744                                ERROR        000550
                                                         FILES        000717
                                                         PRINTS       001174
                                                         RECORD       001233
      PEOT         035216                                PRINTS       001174
      SQRT         035520
      REAOMS       035563
      WRITMS       035716
      --ENTRY-----ACORESS-                                     REFERENCES
```

```
ELMCALC     033445
ALUVC       033756          ELMCALC     033625    033644

PEDT        035217          ALUVC       034723

SQRT        035521          ALUVC       034114    034116    034140    034323    034332

READMS      035564          ELMCALC     033571    033575
                            ALUVC       034003    034013

WRITMS      035717          ALUVC       034645    034655    034666    034677    034710

----UNSATISFIED EXTERNALS-----                                REFERENCES
```

```
                                                                                           033443     106004     106003    000001
CORE MAP  20.13.23.  OVERLAY    04.00    CONTROL
        ---TIME---LOAD MODE --L1--L2-----TYPE---------------USER---++---CALL-------------FWA LOAD--LWA LOAD--BLNK COMN--LENGTH--
        FWA LOADER  123767  FWA TABLES  114376
        -PROGRAM----ADDRESS-                      --LABELED---COMMON--
        KPGEN       041106                                 BCINDEX     000101
                                                           CONST       000544
                                                           CONST1      000475
```

		CUBAT	000477
		FILES	000717
		KADINV	000733
		KHAD	001041
		PRINTS	001174
		RECORD	001233
		SIZE	001262
		RETRIV	001300
		TGAMA	033444
		RGAMA	033455
		W	033461
		D	033500
		S	033511
		AHSTR	033515
		BHSTR	033576
		CHSTR	033657
		EHSTR	033740
		FHSTR	034021
		HHSTR	034102
		GHSTR	034163
		HBMERG	034244
		HBS	035036
		LAYER	035727
		NCOL	035731
		THICK	035732
		HAS	035740
		APSTR	036262
		BPSTR	036334
		CPSTR	036361
		DPSTR	036433
		EPSTR	036460
		GPSTR	036505
		FPSTR	036532
		HAMERG	036557
		APCQ	037054
		APPCPQ	037351
		BBETA	037453
		SLOC	040317
		INSTRS	001401
TRCALC	043360	TGAMA	033444
		RGAMA	033455
CUBRE	043460	CUBAT	000477
		W	033461
		SLOC	040317
DCALC	044726	TGAMA	033444
		D	033500
SCALC	045333	RGAMA	033455
		S	033511
ENERGYA	045631	LAYER	035727
		APSTR	036262
		BPSTR	036334

		CPSTR	036361
		OPSTR	036433
		EPSTR	036460
		GPSTR	036505
		FPSTR	036532
		CONST	000544
		THICK	035732
		HAS	035740
CAPSTR	046113	APSTR	036262
		D	033500
		SLOC	040317
		CUBAT	000477
CBPSTR	046446	BPSTR	036334
		O	033500
		SLOC	040317
		CUBAT	000477
CCPSTR	046742	CPSTR	036361
		O	033500
		SLOC	040317
		CUBAT	000477
CDPSTR	047277	DPSTR	036433
		FPSTR	036532
		D	033500
		SLOC	040317
		CUBAT	000477
CEPSTR	047736	EPSTR	036460
		GPSTR	036505
		S	033511
		SLOC	040317
		CUBAT	000477
HAMERGE	050256	LAYER	035727
		HAMERG	036557
		FILES	000717
		HAS	035740
INSRT	050412	HAMERG	036557
INSRT1	050464	HAMERG	036557
INSA00	050535	HAMERG	036557
ENERGYB	050607	CONST	000544
		FILES	000717
		PRINTS	001174
		THICK	035732
		AHSTR	033515
		BHSTR	033576
		CHSTR	033657
		EHSTR	033740
		FHSTR	034021
		HHSTR	034102
		GHSTR	034163
		O	033500
		S	033511
		TGAMA	033444
		RGAMA	033455

		W	033461
		HBMERG	034244
		HBS	035036
CAHSTR	051134	AHSTR	033515
		D	033500
		SLOC	040317
		CUBAT	000477
CBHSTR	051433	BHSTR	033576
		O	033500
		SLOC	040317
		CUBAT	000477
CCHSTR	052000	CHSTR	033657
		FHSTR	034021
		O	033500
		SLOC	040317
		CUBAT	000477
CEHSTR	052416	EHSTR	033740
		HHSTR	034102
		GHSTR	034163
		S	033511
		SLOC	040317
		CUBAT	000477
HBMERGE	053014	FILES	000717
		HBMERG	034244
		LAYER	035727
		KHAD	001041
		HBS	035036
INSFUL	053211	HBMERG	034244
INSHAF	053247	HBMERG	034244
INSBAO	053305	HBMERG	034244
CHOLESK	053344		
PRESF	055161	ALPHA	053666
		PA	053677
		SCAQ	053716
		HNS	054125
DECOMP	056111	FILES	000717
		LAYER	035727
		KADINV	000733
DECOMPF	056264		
DECOMPM	056432		
FORSUB	056707	FILES	000717
		NCOL	035731
		LAYER	035727
		KADINV	000733
FORSUBF	057067	NCOL	035731
FORSUBM	057206	NCOL	035731
		LAYER	035727
BAKSUB	057361	FILES	000717
		NCOL	035731
		KADINV	000733

		LAYER	035727
BAKSUBM	057532	NCOL	035731
GENB	060005		
WORK	061213	CONST	000544
		CONST1	000475
		PRINTS	001174
		LAYER	035727
		FILES	000717
		BPMAT	060042
		APCQ	037054
		APPCPQ	037351
		OPPFPQ	060251
		OWQQ	060311
		BBETA	037453
		CONTCT	060652
		TQDISP	001324
MATINS	070174		
INVR	070246		
ABCGEN	070646	APCQ	037054
		APPCPQ	037351
		CONST1	000475
		CONST	000544
BMERGE	071773	FILES	000717
		LAYER	035727
		BBETA	037453
ELMMAT	073172	SIZE	001262
		ALPHA	053666
		BPMAT	060042
		FILES	000717
		RECORD	001233
		LAYER	035727
		MATSIZ	001313
		CONTACT	001404
		DWQQ	060311
		BCQQ	072631
		PA	053677
		CONTCT	060652
		INSTRS	001401
		TQDISP	001324
BUILD	100053		
ENERAQ	100147	HNS	054125
		RNAQ1	100114
		RNAQ2	100136
		THICK	035732
		INSTRS	001401
		TQDISP	001324
		SCAQ	053716
ENERBQ	100416	RNBQ1	100317

		RNBQ2	100344
		RNBQ3	100371
		HNS	054125
		THICK	035732
		INSTRS	001401
		TQDISP	001324
BQMERGE	100534	FILES	000717
		LAYER	035727
		HNS	054125
INSRT2	101344		
INSAD2	101406		
ENERQQ	101470	RDNQQ	101446
		RDSQQ	101457
		BCQQ	072631
		HNS	054125
		THICK	035732
		TQDISP	001324
		INSTRS	001401
DNAQ1	102125	RNAQ1	100114
		D	033500
		SLOC	040317
		CUBAT	000477
		INSTRS	001401
DNAQ2	102457	RNAQ2	100136
		D	033500
		SLOC	040317
		CUBAT	000477
		INSTRS	001401
DNBQ1	102747	RNBQ1	100317
		D	033500
		INSTRS	001401
		SLOC	040317
		CUBAT	000477
DNBQ2	103313	RNBQ2	100344
		D	033500
		SLOC	040317
		CUBAT	000477
		INSTRS	001401
DNQQ	103661	RDNQQ	101446
		D	033500
		SLOC	040317
		CUBAT	000477
		INSTRS	001401
DSBQ	104126	RNBQ3	100371
		SLOC	040317
		CUBAT	000477
		D	033500
		INSTRS	001401
PRODUCT	104467		
SINCOS	104607		
SQRT	104706		
ASINCOS	104751		

```
REAOMS     105107
SECOND     105242
BUFFEI     105253
BUFFEO     105363
IOCHEK     105467
REWINM     105561
WRITMS     105644
CPUSYS     105745
--ENTRY-----ADDRESS-                                    REFERENCES
KPGEN      041107
TRCALC     043361       KPGEN     041512

CUBRE      043466       KPGEN     041422   041433

DCALC      044727       KPGEN     041520

SCALC      045334       KPGEN     041525

ENERGYA    045632       KPGEN     041526

CAPSTR     046114       ENERGYA   045633

CBPSTR     046447       ENERGYA   045634

CCPSTR     046743       ENERGYA   045635

CDPSTR     047300       ENERGYA   045636

CEPSTR     047737       ENERGYA   045637

HAMERGE    050257       ENERGYA   046003

INSRT      050413       HAMERGE   050316   050321   050324   050327   050332

INSRT1     050465       HAMERGE   050271   050274   050277

INSADD     050536       HAMERGE   050336   050341   050356   050361

ENERGYB    050610       KPGEN     041527

CAHSTR     051135       ENERGYB   050611

CBHSTR     051434       ENERGYB   050612

CCHSTR     052001       ENERGYB   050613

CEHSTR     052417       ENERGYB   050614

HBMERGE    053015       ENERGYB   051014

INSFUL     053212       HBMERGE   053050   053054   053110   053112   053114   053120   053124
                                  053160   053162
```

INSHAF	053250	HBMERGE	053026	053030	053046	053052	053056	053116	053122
			053126	053164	053166				
INSBAO	053306	HBMERGE	053063	053073	053133	053143			
CHOLESK	053345	KPGEN	041607						
PRESF	055175	KPGEN	041741	041761					
DECOMP	056112	KPGEN	041622						
DECOMPF	056265	DECOMP	056142						
DECOMPM	056433	DECOMP	056207						
FORSUB	056710	KPGEN	041654						
FORSUBF	057070	FORSUB	056747						
FORSUBM	057207	FORSUB	057023						
BAKSUB	057362	KPGEN	041661						
BAKSUBM	057534	BAKSUB	057455	057460					
GENB	060006	FORSUB	056740	057004					
WORK	061220	KPGEN	041706	041716					
MATINS	070177	WORK	063665	063671	063675	063701	063711	063715	063725
			063731	063741	063745	063751	063755	063765	063771
			064001	064005					
INVR	070247	WORK	063470						
ABCGEN	070647	WORK	062035						
BMERGE	071774	WORK	064043						
ELMMAT	073202	KPGEN	042046	042062					
BUILD	100054	ELMMAT	073267	073424	073720				
ENERAQ	100150	KPGEN	041530						
ENERBQ	100417	KPGEN	041531						
BQMERGE	100535	ENERBQ	100504						
INSRT2	101345	BQMERGE	100551	100554	100573	100576	100601		

INSA02	101407	BQMERGE	100605	100622					
ENERQQ	101471	KPGEN	041532						
ONAQ1	102126	ENERAQ	100177						
DNAQ2	102460	ENERAG	100200						
ONBQ1	102750	ENERBQ	100441						
DNBQ2	103314	ENERBQ	100442						
DNQQ	103662	ENERQQ	101510						
DSBQ	104127	ENERBQ	100443						
PROOUCT	104473								
SIN	104610	TRCALC	043402						
		CUBRE	043674	043722	043753	044001	044032	044060	
COS	104613	TRCALC	043404						
		CUBRE	043676	043724	043755	044003	044034	044062	
SQRT	104707	CUBRE	044277	044375					
		CHOLESK	053447						
		DECOMPF	056316	056370					
		OECOMPM	056545	056633					
		WORK	061460						
		ABCGEN	070757						
ASIN	104755								
ACOS	104752	CUBRE	043704	043763	044042				
READMS	105110	KPGEN	041330	041334	041340	041344	041350	041354	041360
			041367	041373	041461				
		FORSUB	056732	056774					
		BAKSUB	057405	057427	057435				
		ELMMAT	073317	073474	073601	073754			
SECOND	105242	KPGEN	041124						
BUFFEI	105254	KPGEN	041576	041577	041600				
		OECOMP	056126	056130	056132	056154	056161	056165	
		ELMMAT	073240	073245	073252	073376	073403	073410	073671
			073676	073703					
BUFFEO	105364	HAMERGE	050302	050303	050304	050344	050345	050346	050364
			050365	050366					
		HBMERGE	053033	053034	053035	053066	053067	053070	053076
			053077	053100	053136	053137	053140	053146	053147
			053150	053171	053172	053173			
		BMERGE	072020	072021	072022	072065	072066	072067	072114

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                                         072115    072116
                              ELMMAT     074230    074235    074242
                              BQMERGE    100557    100560    100561    100610    100611    100612    100625
                                         100626    100627

     IOCHEK       105470      KPGEN      041602
                              HAMERGE    050306    050350    050370
                              H3MERGE    053037    053102    053152    053175
                              DECOMP     056135    056170
                              BMERGE     072024    072071    072120
                              ELMMAT     073260    073416    073711    074250
                              BQMERGE    100563    100614    100631

     REWINM       105562      KPGEN      041375    041401    041403    041405    041554    041556    041671
                                         041720    042146
                              DECOMP     056115
                              ELMMAT     073230    073366    073654

     WRITMS       105645      KPGEN      041612
                              DECOMP     056220    056237
                              FORSUB     056754    057036
                              BAKSUB     057470

     MSG=         105775
     RCL=         105762
     SYS=         105747      SECOND     105244

     WNB=         105766
     ----UNSATISFIED EXTERNALS-----                  REFERENCES




CORE MAP  20.13.31.  OVERLAY    05.00    CONTROL                                   033443    036674    036673    000001
     ---TIME---LOAD MODE --L1--L2-----TYPE---------------USER---++---CALL-------------FWA LOAD--LWA LOAD--BLNK COMN--LENGTH--
     FWA LOADER  123767  FWA TABLES  120411
     -PROGRAM----ADDRESS-                 --LABELED---COMMON--
     ASMBLE      033444                           BCINDEX     000101
                                                  ERROR       000550
                                                  FILES       000717
```

```
                                                        PRINTS     001174
                                                        RECORD     001233
                                                        SIZE       001262
                                                        RETRIV     001300
                                                        MATSIZ     001313
                                                        CONTACT    001404

MERGE      033777                                       BCINDEX    000101
                                                        CONTACT    001404
                                                        ERROR      000550
                                                        FILES      000717
                                                        PRINTS     001174
                                                        RECORD     001233
                                                        SIZE       001262
                                                        RETRIV     001300
                                                        MATSIZ     001313
READMS     036103
SECOND     036236
BUFFEI     036247
IOCHEK     036357
REWINM     036451
WRITMS     036534
CPUSYS     036635
--ENTRY-----ADDRESS-                                           REFERENCES
ASMBLE     033445
MERGE      034000          ASMBLE     033554    033617

READMS     036104          MERGE      034015    034449    034647    034660    034745

SECONO     036236          ASMBLE     033464    033621

BUFFEI     036250          MERGE      034157    034164    034171

IOCHEK     036360          MERGE      034177

REWINM     036452          MERGE      034153

WRITMS     036535          MERGE      034142    034426    034634    035062    035077

MSG=       036665
RCL=       036652
SYS=       036637          SECONO     036240

WNB=       036656
----UNSATISFIED EXTERNALS-----                                 REFERENCES
```

```
CORE MAP  20.13.34.  OVERLAY    06.00    CONTROL                                                   033443     035613     035612     000001
          ---TIME---LOAD MODE --L1--L2-----TYPE---------------USER---++---CALL-------------FWA LOAD--LWA LOAD--BLNK COMN--LENGTH--
          FWA LOADER  123767  FWA TABLES  120437
          -PROGRAM----ADDRESS-                         --LABELED---COMMON--
          SOLMAT      033444                                    BCINDEX     000101
                                                                FILES       000717
                                                                ERROR       000550
                                                                PRINTS      001174
                                                                RECORD      001233
                                                                SIZE        001262
                                                                RETRIV      001300
                                                                MATSIZ      001313
                                                                CONTACT     001404

          SOLV        033717                                    BCINDEX     000101
                                                                ERROR       000550
                                                                FILES       000717
                                                                PRINTS      001174
                                                                RECORD      001233
                                                                SIZE        001262
                                                                RETRIV      001300
                                                                MATSIZ      001313

          EMULT       034771                                    ERROR       000550
          NEWGEMP     035002                                    FILES       000717
                                                                PRINTS      001174
                                                                RECORD      001233
                                                                MATSIZ      001313

          READMS      035307
          SECOND      035442
          WRITMS      035453
          CPUSYS      035554
          --ENTRY-----ADDRESS-                                       REFERENCES
          SOLMAT      033445              SOLMAT     033476
          SOLV        033720

          EMULT       034771              SOLV       034065     034252

          NEWGEMP     035012              SOLMAT     033610     033622

          READMS      035310              SOLV       033754     033764     034157     034303     034322     034441
                                          NEWGEMP    035037     035050     035057     035162

          SECOND      035442              SOLMAT     033464     033500
```

```
WRITMS      035454         SOLV        034114    034150    034313    034601
                           NEWGEMP     035145    035224

MSG=        035604
RCL=        035571
SYS=        035556         SECONO      035444

WNB=        035575
----UNSATISFIED EXTERNALS-----                         REFERENCES




CORE MAP  20.13.36.  OVERLAY    07.00    CONTROL                                     033443    036422    036421    000001
          ---TIME---LOAD MODE --L1--L2-----TYPE---------------USER---++---CALL-------------FWA LOAD--LWA LOAD--BLNK COMN--LENGTH--
          FWA LOADER  123767  FWA TABLES  120351
          -PROGRAM----ADDRESS-                      --LABELED---COMMON--
          FLEX        033444                                BCINDEX     000101
                                                            ERROR       000550
                                                            FILES       000717
                                                            PRINTS      001174
                                                            RECORD      001233
                                                            SIZE        001262
                                                            RETRIV      001300
                                                            MATSIZ      001313
                                                            CONTACT     001404

          INITB       034216
          SOLVMOR     034415                                FILES       000717
                                                            RECORD      001233
                                                            MATSIZ      001313
                                                            CONTACT     001404
                                                            PRINTS      001174
          SPCPRT      035752
          EMULT       036071
          SQRT        036122
          READMS      036165
          WRITMS      036320
          --ENTRY-----ADDRESS-                                  REFERENCES
          FLEX        033445
          INITB       034226         FLEX        033634    033646

          SOLVMOR     034416         FLEX        033733
```

```
SPCPRT     035753
EMULT      036072          SOLVMOR    034653   034667   035111   035125

SQRT       036123          FLEX       034036

READMS     036166          FLEX       033500   033547   033621   033760   033770
                           SOLVMOR    034505   034524   034774   035153   035212   035270   035336

WRITMS     036321          FLEX       033652
                           SOLVMOR    034713   034756   035173   035240   035253   035560

----UNSATISFIED EXTERNALS-----                         REFERENCES




CORE MAP  20.13.40.  OVERLAY   10.00    CONTROL                                           033443    036164    036163    000001
   ---TIME---LOAD MODE --L1--L2-----TYPE---------------USER---++---CALL-------------FWA LOAD--LWA LOAD--BLNK COMN--LENGTH--
   FWA LOADER  123767  FWA TABLES  120431
   -PROGRAM----ADDRESS-                         --LABELED---COMMON--
   CONTACT     033444                                 BCINDEX     000101
                                                      ERROR       000550
                                                      FILES       000717
                                                      PRINTS      001174
                                                      RECORD      001233
                                                      SIZE        001262
                                                      RETRIV      001300
                                                      CONTACT     001404
                                                      MATSIZ      001313

   INITAB      034046
   INITC       034106
```

```
UPDTAX     034244
UPDTAX2    034534
MAXMUM     035112                                   PRINTS     001174
LINSYS     035214
ACGOER     035715
READMS     035727
WRITMS     036062
--ENTRY-----ADDRESS-                                           REFERENCES
CONTACT    033445
INITAB     034047          CONTACT     033547

INITC      034111          CONTACT     033522     033527

UPDTAX     034255          CONTACT     033643     033661

UPDTAX2    034546          CONTACT     033723     033741

MAXMUM     035113          UPDTAX      034462
                           UPDTAX2     034635

LINSYS     035215          UPDTAX      034360
                           UPDTAX2     034732

ACGOER     035716          LINSYS      035405     035524

READMS     035730          CONTACT     033512     033606     033612     033675
                           INITC       034130

WRITMS     036063          CONTACT     033745     033751     033755
----UNSATISFIED EXTERNALS-----                                 REFERENCES
```

REFERENCES

1. Deak, A. L., and Atluri, S., "The Stress Analysis of Loaded Rolling Aircraft Tires," Volume I, Analytical Formulation, Research Contract Final Report, Contract No. F33615-73-C-3002.

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Mathematical Sciences Northwest, Inc. 4545 Fifteenth Avenue Northeast Seattle, Washington 98105	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP N/A

3. REPORT TITLE

Stress Analysis of Loaded Rolling Aircraft Tires - Computer Program

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Technical Report - 9 October 1972 through 9 October 1973

5. AUTHOR(S) (First name, middle initial, last name)

A. L. Deak, R. C. Johnston

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
October 1973	80	0

8a. CONTRACT OR GRANT NO. F33615-73-C-3002 b. PROJECT NO. c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) N/A 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) AFFDL-TR-73-130 Vol II

10. DISTRIBUTION STATEMENT

Distribution limited to U. S. Government Agencies only; test and evaluation; statement applied Oct. 1973; other requests for this document must be referred to AFFlight Dynamics Lab.AFFDL/FEM,WPAFB,Ohio

11. SUPPLEMENTARY NOTES N/A	12. SPONSORING MILITARY ACTIVITY Air Force Flight Dynamics Laboratory Air Force Systems Command Wright-Patterson Air Force Base, Ohio

13. ABSTRACT

Presented is a description of the FORTRAN/COMPASS computer code for the large deflection stress analysis of multi-layered aircraft tires. The program is modulated into nine overlays within the framework of dynamic storage allocation and is operational on the CDC-6600 machine under the SCOPE 3.3 system.

DD FORM 1 NOV 65 1473

Security Classification

UNCLASSIFIED

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Tire mechanics Shells Finite Elements Stress Analysis Cord-Rubber Composites						

UNCLASSIFIED

Security Classification

☆U.S.Government Printing Office: 1974 — 758-431/403